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LECTURE.

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FIELD MARSHAL SIR JOHN F. BURGOYNE, Bart., G.C.B., &c., &c., in the Chair.

GUN-COTTON APPLIED TO DEMOLITIONS.

By Colonel A. à'COURT FISHER, C.B., R.E.

MANY years have elapsed since experiments were commenced with various explosive compounds, which were intended to rival or to supersede gunpowder in many or all of the uses to which it is applied for civil as well as for warlike and destructive purposes. It is not my intention to take up the time of this meeting by entering upon a recapitulation of the various phases and shapes in which compounds different in form, though somewhat similar in essentials, have from time to time claimed the attention of the public; but it is necessary to say a few words in order to bring us to the position in which we now stand with reference to the subject which I am placing before you to-day.

The first compound to which I shall allude is a substance which was described by Braconnet in the Annales de Chimie in 1833. This substance which was called Xyloidine was obtained by the action of concentrated nitric acid on starch and saw-dust.

In 1838, Pelouze drew attention again to a similar substance, which he was the first to produce from cotton fabrics and paper, to which he gave the name Pyroxiline, and which he considered to be susceptible of application for artillery purposes. Many will recognize here the germs of gun-cotton, and of Schultz's saw-dust powder. In 1847, Professor Schönbein obtained a patent for the manufacture of gun-cotton, the cotton being said to be rendered so explosive as to form an excellent substitute for gunpowder. The process is exceedingly simple, consisting only in thoroughly soaking the rough cotton wool, free from

all extraneous matter, in a mixture of sulphuric and nitric acids in the proportions of 3 to 1. When the cotton is thoroughly soaked, the acids are poured off, and by a system of pressing and washing, the cotton is thoroughly freed from them, being afterwards washed in a solution of carbonate of potash, in order still more surely to effect the expulsion of the acid by the alkaline application.

Schönbein's gun-cotton was much experimented with, both by the French and Austrian Governments, and though when carefully made in small quantities, favourable results were obtained, yet when manufactured and experimented with on a large scale, failures occurred, and in both countries serious explosions took place, which, being generally attributed to the spontaneous combustion of the cotton, threw the material into great disfavour abroad.

Nor were we not, however, neglectful in this country, for soon after Professor Schönbein's discovery, Messrs. Hall of Faversham made gun-cotton in considerable quantities; but they in their turn experienced a fatal explosion.

Baron von Lenck, of Austria, who had continued to work at the subject of gun-cotton from the time of Schönbein's discovery, made some decided improvements in the general method of its manufacture, and also elaborated certain modes of applying it, which appeared at first to furnish promising results; and somewhat extensive experiments were made from time to time by the Austrian Government up to 1862, by his direction, but without any great practical success.

In 1863, General von Lenck's improvements were communicated by the Austrian Government to that of this country. Ultimately, a Government Committee was appointed by the War Office to investigate the general subject of the application of gun-cotton; the investigation into the manufacture and keeping qualities of the material being entrusted to Mr. Abel, F.R.S., Chemist to the War Department, who carried on for several years an experimental manufactory at the Government powder works at Waltham Abbey. About this time Messrs. Prentice, of Stowmarket, also commenced the manufacture of gun-cotton upon Baron von Lenck's principle.

Up to the period of which we are now speaking, the custom which prevailed in making gun-cotton was to soak the cotton in the form of skeins of yarn after cleansing, then to wash and thoroughly get rid of the acid; after which the skeins of yarn were twisted up into what was termed gun-cotton rope, of a diameter suitable for the purpose for which it might be intended. In some cases, where rapidity of explosion was much desired, the yarn was twisted into ropes with a hollow core in the centre, through which it was considered that the flame first generated would rapidly penetrate to all parts of the charge.

The two great essentials in the preparation of the gun-cotton, and which gave the greatest trouble in the manufacture, were the thorough, equable impregnation of the cotton fibre with the acids, and the subsequent complete separation of those portions of the acid which do not enter into the chemical change.

Though the manufacture was conducted without accident, and good results were obtained in many experiments, yet they were not altogether

satisfactory; implicit reliance could not be placed on the action of the cotton when employed in any considerable quantity; the results could not be foretold with confidence, the explosions were unequal, as also appeared to be the quality of the gun-cotton; and it became evident that we were yet on the threshold of the knowledge of how to manufacture and to employ it.

A course of experiments carried on in 1865, at Woolwich, soon sufficed to show that gun-cotton, as then manufactured, was not suitable for artillery purposes. The great local violence of its action, and rapidity of its ignition when confined, as in the chamber of a gun, rendering it extremely destructive to the piece.

Experiments were made with a view to diminish the destructive energy of the gases generated on the combustion of the cotton, but so far as they were carried out, it appeared that in reducing its explosive force, and diminishing these destructive effects, its power as a propelling agent was similarly reduced, and it was for the time decided to give up the idea of employing it for artillery. It has, however, still many supporters as an explosive for sporting purposes, though I am not aware that when made of such strength as to cease to be injurious to the gun, any great superiority over gunpowder, as regards hard hitting, is proved for it, though undoubted benefits arise from its freedom from smoke and fouling.

Though it appeared that gun-cotton possessed an intensity of action at the moment of explosion, which rendered it dangerous when employed in guns, in its strong or undiluted condition, and therefore that it was unsuitable for artillery purposes; there seemed no doubt but that this very destructive quality might be of great service to the engineer in mining operations, demolitions, &c., for some of which purposes the violent local action would be of the utmost value.

In 1866, Mr. Abel invented a process of manufacture of gun-cotton, by means of which a far greater uniformity of quality is secured, and the manufacture can be conducted with an almost certain immunity from danger, whilst the substance is at the same time put into the form most convenient for storage, for transport, and for use. Some preliminary experiments were made with it in 1866-67, with 12-pounder guns, which gave promising results, but they have been interrupted by the dissolution of the Gun-cotton Committee, in 1868.

Mr. Abel's process consists in reducing the gun-cotton into pulp. It is found that in this condition, the cotton is most easily relieved of the superfluous acids, by means of washing and pressure. The pulp in drying can be moulded into any convenient form; that generally approved being discs of $\frac{7}{8}$ to 7 inches in diameter, and $\frac{1}{4}$ to 2 inches in thickness. For convenience of transport in bulk, it could be pressed into planks or boards, and for certain purposes, it can be broken up into small pieces, and employed in a coarsely granulated form.

Mr. Abel's cotton is correctly termed "compressed gun-cotton," and in this form and under this title, gun-cotton has assumed in this country an importance far greater than it has acquired at any time in any other. It is at present largely employed for blasting in slate and other quarries in Great Britain, and its manufacture, for this purpose, has reached the

amount of 100 tons annually. It is with this material that experiments have, during the last two years, been conducted from time to time by Officers of the Royal Engineers, and it is to those experiments that I desire to draw your attention to-day.

Manufacture of "Compressed Gun-Cotton."

Compressed gun-cotton is manufactured exclusively by Messrs. Prentice, of Stowmarket, and the process has been so perfected by them that there appears now to be little or nothing to be desired. The essential points, viz., complete impregnation of the cotton with the acid, thorough washing out of the superfluous acid, and uniformity of quality being brought, so far as can now be seen, almost to perfection. Another most important point in the manufacture is the perfect safety enjoyed during the whole process, for at no stage is the gun-cotton combustible until the very last moment, when it is packed in boxes to be sent away; even then it is only inflammable, being inexplosive until fired by detonation.

Refuse cotton, but clean and free from impurity, is used. It is first thoroughly dried in hot chambers, for if the slightest moisture were left in the cotton when it is soaked in the acids, chemical heat would be generated in the mass, and the decomposition of the cotton would ensue. The dry cotton is weighed out into pounds, and each pound is put into a compartment in a trough and soaked in 150 lbs. of the mixed acids. Each pound will take up about 12 times its own weight of acid, but the compartments are each charged with the larger quantity, in order to admit of the cotton being freely stirred about, and thoroughly impregnated with acid. This process is carried on for about ten minutes, when the cotton is taken out with a ladle, and put to strain on a grating over each compartment, a certain amount of acid is pressed out back into the trough, and the cotton is carried away in cylindrical jars, to be further pressed by means of a screw; an amount of fresh acid equal to that taken away with the cotton being placed in the trough for the next batch.

The gun-cotton, now containing twelve times its weight of acid, is left to stand for twenty-four hours, and in order to secure uniformity in quality, and that the whole batch may be under precisely similar circumstances of temperature, the jars are put to stand in water in a shallow vat. At the end of this period, every little knot or hard piece of cotton has been thoroughly soaked, and it becomes necessary to get rid of the superfluous acids.

The gun-cotton is turned out of the jars into a revolving copper drum with finely-perforated sides and bottom, contained within an outer case, and the drum is rapidly whirled round by a band in connection with steam machinery, at the rate of about 1,000 revolutions per minute, thus about $\frac{7}{12}$ of the acid is got rid of by the centrifugal action, and is saved.

As said before, the presence of any water in the cotton when soaked in the acid, would be destructive, and the question is how to wash out

the superfluous acid now remaining. Wooden vats are provided, into which a strong stream of water pours from a height through a broad shoot, and into this the cotton is tumbled, and continually stirred, the result being that the acid is knocked out of the cotton by the force of the water before sufficient time has elapsed to allow of any decomposition. In about seven or eight minutes, no taste of acid can be found, and the cotton is taken out and partially dried in another set of centrifugal machines, and carried off to another building. Here the cotton is thrown into a large vat containing water, in which is fitted a wheel with cutting knives attached, which, as the wheel revolves, pass very closely over a steel plate. The wheel is set in motion by steam machinery, and the cotton is stirred about, and a current induced which carries it under the wheel. The gun-cotton is by this means very finely divided, whilst the washing process is still being carried on.

It is then transferred to pulping-machines. These consist of vats in which are revolving wheels with paddles. It is here knocked about and washed for forty-eight hours, fresh water being supplied as the dirty is removed. For the removal of the latter, small holes are provided in the bottom of the vats beneath the wheel, and it might be supposed that the cotton in its finely-divided state would pass away with the water. Not so, however; it is found when drawn down over the holes to form a species of filter, through which the water runs clear. When so large a quantity has accumulated as to check the current, the waste tap is closed, and a supply-tap in the same pipe being turned, water is forced up to clear the holes. Towards the close of the forty-eight hours, the gun-cotton is tested, a small portion being taken as a sample, one test being the temperature at which it will burn, the standard adopted being 340° Fah.; it is also tested for acid. If the tests are satisfactory the vats are cleared; if not, the pulping is continued.

The cotton is then dried in the centrifugal machine, working 1,200 revolutions per minute for about a quarter of an hour. After this it contains 30 per cent. of water. In this form, it is weighed out into charges, still incombustible.

The process which I shall describe is that of making the mining charges; large discs and sporting cartridges being specially made. For mining, *i.e.*, blasting purposes, all charges are equal, 26 of them weighing 1 lb. They vary in diameter from $\frac{7}{8}$ of an inch to $1\frac{3}{4}$ inch, according to the size of tool and custom of the place where they are used.

The cotton is washed down into iron cylinders or tubes with water, and first pressed down by a hand-lever until it acquires a tolerably hard consistency. In the case of a $\frac{7}{8}''$ charge—the smallest—the gun-cotton after this process is a cylinder 8″ in length, solid, with the exception of a hole down the centre. A number of these are then put in other tubes on a revolving cam, which brings them in succession under a pressure of 2 tons, reducing the charge to a length of about 2 inches.

The larger charges which are better to handle, being not so long, are differently and more quickly pressed after the first compression with the hand-lever, by placing them in sockets in a heavy iron frame

with a vertical face. A parallel plate, on which are attached iron pins which are opposite to and fit the sockets, is then brought up by a hydraulic press with 12-inch ram, and the charges are compressed with a pressure of about 4 tons per inch over the surface of the charges. This pressure of 160 tons, which is a constant quantity, is sufficient for the compression of a 7-inch disc, the largest made, and the number of smaller charges subjected to it, is regulated in proportion. The total surface of the charges or discs pressed being always made equal to the area of a circle of a diameter, of 7 inches.

In this process a quantity of water is pressed out through the hole which is left in the centre of each disc, which now contains 20 per cent. of water, and is still uninflammable.

A parchment-like, water-proof covering, made by soaking fine blotting-paper in sulphuric acid, and afterwards washing it in dilute ammonia, is then pasted round the disc, which now only requires the drying process; this is effected by placing a layer of discs on a tray under which steam pipes are laid. After eight hours, the discs are dry and fit to be packed, and it is not until then that they are inflammable, and even then they are not explosive until fired by detonation. This has been proved by the occasional ignition of a tray of discs from an accidental spark, from which no result more serious than the loss of the cotton has ever occurred. When packed in boxes, for transport, the cotton still remains inexplosive, experiments having been tried by actually igniting charges of from 5 to 20 lbs. in these cases. The cotton is made up in whole, half, and quarter boxes, containing 20 lbs., 10 lbs., and 5 lbs. respectively, and equivalent to barrels, half, and quarter barrels of powder.

Before entering upon the details of the different classes of experiments made, I will enumerate the advantages and defects supposed to be attributable to compressed gun-cotton, so far as we are at present aware of its properties and capabilities.

1st. Compressed gun-cotton, if affected by damp, can be re-dried simply by exposure to the sun, or a gentle heat, without risk of explosion or deterioration of its explosive qualities; therefore, in case of fire in the neighbourhood of a magazine containing gun-cotton, it may be rendered inexplosive by the application of water, and be readily dried afterwards without the explosive qualities of the cotton having become impaired.

2nd. Compressed gun-cotton, if accidentally ignited in the open air, or under any circumstances, unless very strongly confined, will burn freely and intensely until consumed, but without any explosion. Thus the risk of danger in storing it, and of damage to it when stored, may be held to be at a minimum as compared with other explosive compounds.

3rd. The strength or energy of this gun-cotton, when properly exploded, may be held to be from 2½ to 5 times that of gunpowder by weight, according to the circumstances under which it is employed and the manner in which it is exploded.

4th. It can be exploded by very simple means in a perfectly simple

manner, and with full destructive effect, without the necessity of enclosing it in any case or envelope. This process will, however, be alluded to shortly.

With regard to the disadvantages, they seem to exist mainly in our ignorance as to the qualities of the material and of the manner in which to employ it. It appears that, as in the old experiments made in foreign countries so in the present, we generally obtain certain preconceived results in small trials, but when large charges have been employed, the results have not always been as anticipated, nor so regular for comparison as those obtained from gunpowder explosions.

A so-called failure has occasionally occurred, and it has been attributed to faulty cotton, to damp, or to incomplete ignition; and though very great advance has been made in improvements on all these heads, we have yet much to learn which can only be taught us by many well-considered and carefully-observed experiments. With regard to the manufacture, I believe that the cotton can now be perfectly made; with regard to its keeping qualities, continued observation is undoubtedly desirable and is being carried on. It must, I think, meanwhile be admitted that, considering the short time during which gun-cotton has claimed the public attention, very great strides have been taken towards bringing it entirely under control and utilizing it for peaceful and warlike purposes.

The experiments to which I shall refer were, many of them, made prior to the perfection of the process of manufacture as now carried on by Mr. Prentice, in which it appears that, from the great care and precautions adopted, a very great regularity or uniformity in the quality of the material is secured; and there is no doubt but that, in all future trials, one great source of embarrassment and difficulty in conducting comparative experiments will prove to have been swept away.

It will have been observed that I have more than once in speaking of gun-cotton, alluded to the mode of igniting it, as being a matter of some importance. To anyone who has only seen gunpowder ignited in various ways, whether by the fire of a percussion cap, as in a modern gun, or by a spark, as in the old flint gun, or by the flame of a match or port fire, it will appear that *ignition* is *ignition* however obtained, and that an explosion, of an extent apparently only commensurate with the charge, will be the certain result; the only modification being that the powder if loose will go off, as a schoolboy would say, with a puff, but if confined, with a bang. With gun-cotton, however, this is not the case. Compressed gun-cotton, when unconfined, will, when ignited with a match, burn with an intensely hot white flame until consumed, much more slowly than the powder, and without any puff whatever; in a bag, or light case, a charge of commensurate amount will produce a species of explosion, and all the cotton will be consumed, but if the charge be disproportionate in amount to the strength of the case, the latter will burst, a certain amount of cotton will be consumed, and the remainder will be scattered abroad.

This was clearly shown in the results of some small scale experiments, made at Chatham in 1865, by the Royal Engineers, for the information of the Committee on Floating Obstructions and Torpedoes.

Some small charges of both gunpowder and gun-cotton were fired under water in cases of sheet tin soldered, and it was found that where a charge of only 4 ozs. of cotton was fired, the case was burst and a considerable proportion of the cotton floated up to the surface un-ignited, the only noticeable effect being a flight of bubbles of gas to the surface; whilst, when a similar charge was completely ignited in a stronger case, the explosion was comparatively violent and accompanied by a loud report. A charge of powder of any reasonable amount might have been ignited in such a case, though not with the maximum of effect. It is now an undoubted fact that, in order to develop to the fullest extent the effect of the explosion of a charge of gunpowder, it is necessary to put it under a certain amount of restraint at the moment of ignition. This will not be disputed by anyone who has thought on the subject, and the fact of the amount of unconsumed powder blown from the mouth of an over-charged or short-barrelled gun will bring conviction with it; but I mention it in order to show the extent to which the strength of the case in which a powder charge is confined affects the result. In a series of experiments with small charges of gunpowder fired under water, it was found that with 4 lbs. of powder the maximum effect was not produced until it had been enclosed in a case of wrought iron of $\frac{1}{5}$" in thickness.

With gun-cotton it was found that the strength of the case had to be still further increased for an equivalent charge, and this fact gave rise to great doubts as to whether it could ever be economically applied in large quantities for engineering purposes, in consequence of the cost of providing cases of suitable strength to develop the full force of the charges.

An exceedingly valuable discovery was made by Mr. Brown, Assistant in the Chemical Laboratory of the War Department in 1868, viz., that by igniting compressed gun-cotton by means of a fuze charged with a detonating composition, the full force of the explosion would be obtained, even were the charge of cotton entirely unconfined. It was found by experiment that so complete was the ignition by this means, that not only could a loose heap of cotton discs be thoroughly ignited by firing such a fuze in contact with an outer disc, but that a row of discs, separated from each other by a distance of an inch would be instantaneously exploded with equal certainty by a fuze attached to one of the extreme discs; the ignition being equally efficacious if the charge was fired from a central disc.

The value of this discovery can hardly be overrated; for no preparation is necessary to change the gun-cotton from the comparatively harmless substance, inexplosive when touched by fire alone, into the wonderful explosive agent, the services of which may be suddenly called into requisition; the entire secret lying in the difference between ignition by fire and ignition by detonation.

I shall now pass over the many earlier experiments, and start with the substance known as "Abel's compressed gun-cotton," fired with a "detonating fuze," and speak of the various experiments made by Officers of Royal Engineers with this substance.

The principal uses to which an Engineer would apply gunpowder or gun-cotton would be:—

1. Blasting in quarries, tunnels, or mines.
2. Military mines of attack or defence.
3. Demolition of retaining walls, as in the destruction of fortifications.
4. Blasting walls, as in the destruction of large buildings. (This was done in the demolition of the Exhibition building of 1862.)
5. Hasty demolition of any large buildings when there is no time for making preparation beyond simply placing the charge within the building.
6. Hasty demolition of stockades.
7. Blasting in timber, for the demolition of wooden bridges or piers.
8. Blasting rocks under water, and demolition of wrecks.
9. Destruction of vessels by torpedoes.

1. *Blasting in Quarries, Tunnels, or Mines.*

There appears but little left to be said with reference to the economical application of gun-cotton for quarrying, when I state that the sale of compressed gun-cotton for these purposes has reached the amount of 100 tons per annum, equivalent, for purposes of work, to at least 500 tons of gunpowder, and there can be but little doubt of its doing its work safely and well. It will, roughly speaking, do five times the work at about four times the cost, of cheap blasting powder. The work is said to be as well, if not better done; complete safety being secured at the same time.

The locality where it has obtained this strong footing is North Wales, where it is used for blasting in slate. Mr. Prentice has showed great judgment in the manner in which he has brought it forward, respecting the habits and traditions of the quarrymen rather than forcing upon them new methods, weights, measures, &c. He found that the practice was to charge the holes by measure and not by weight, the measure employed being a tin pot or "tot," which was found to contain $\frac{1}{3}$ lb. Mr. Prentice adopted that as his standard of charge, and finding the comparative strength of the two materials as one cotton to five gunpowder, nearly, he makes his mining charges all 26 to the lb., whatever may be the diameter of the disc. Each miner, therefore, looks on a disc as equivalent to a *tot* of gunpowder, and no mistakes can arise in loading.

Compressed gun-cotton has also been employed with great success in Australia in tunnelling in granite; it has been found to possess a great superiority over gunpowder in narrow works, as in tunnels or mines, from the freedom from smoke after an explosion. Dr. Angus Smith speaks highly of this quality as relieving the miners from the injurious effects of breathing a smoky and impure atmosphere. It also is conducive to a great saving of time in consequence of no delay in the work being necessary in order to clear the mine from smoke after an explosion.

The charges are packed in boxes containing 20 lbs., 10 lbs., and 5 lbs. respectively, which represent one barrel, half barrel, and a quarter barrel of gunpowder. There is a conventional mark on each box, a circle representing a whole box, a semicircle half a box, and a quadrant a quarter box.

The material is scientifically manufactured, ingeniously and cleverly arranged with great intelligence, and put into such a shape that in the hands of the most illiterate, uneducated miner, there is scarcely a chance left of a mistake in its use, or of any accident involving risk of life or limb.

Where gunpowder has been used for quarrying, a certain amount of risk has from the earliest times been incurred, in consequence of the necessity for what is called tamping the charge; *i.e.*, after the hole has been bored, and a sufficient amount of powder has been poured into the hole, it has to be filled up as solid as possible to such a height as to preclude the risk of the powder simply blowing upwards out of the hole again as from a gun. The substance usually employed was clay or pounded brick, and as this was rammed down over the charge there was a risk of explosion if great care was not taken, and a copper rammer employed. Frequent accidents have happened to the miners from this cause, and a considerable amount of time is taken up in tamping. It is found, however, that gun-cotton when ignited with a percussion fuze, acts with a perfect effect at the bottom of a hole without the employment of any tamping whatever. Hitherto the miners have not availed themselves very generally of this advantage, they continue to use the time-fuze with tamping: a saving in time and an increased effect would, however, be secured by the adoption of the detonating fuze or primer.

With gunpowder, there is always a risk in the loose powder which might be lying about; it happens often, from its being carried in a leaky vessel, that a train has been formed leading to a large quantity or store of powder, which might be ignited by sparks, by matches dropped and trodden on, by ashes from pipes, or fire communicated in many such ways. But with the cotton all this danger is swept away, the cotton may light and burn, but until the fire has been communicated by detonation, the fuze being at the same time in contact with the gun-cotton, an explosion is impossible. It is, in fact, like a Bryant and May's safety match, it cannot be exploded except by the means specially provided for the purpose.

In order to secure the most efficient and economical work in rock of various natures, the density of the cotton is made to increase with the hardness and density of material in which it is to be employed; the economy attending the employment of the cotton being found to increase with the hardness of the rock.

2. *Military Mining.*

Before entering on the description of any experiments in military mining, it is necessary, in order to make the matter clear to those who

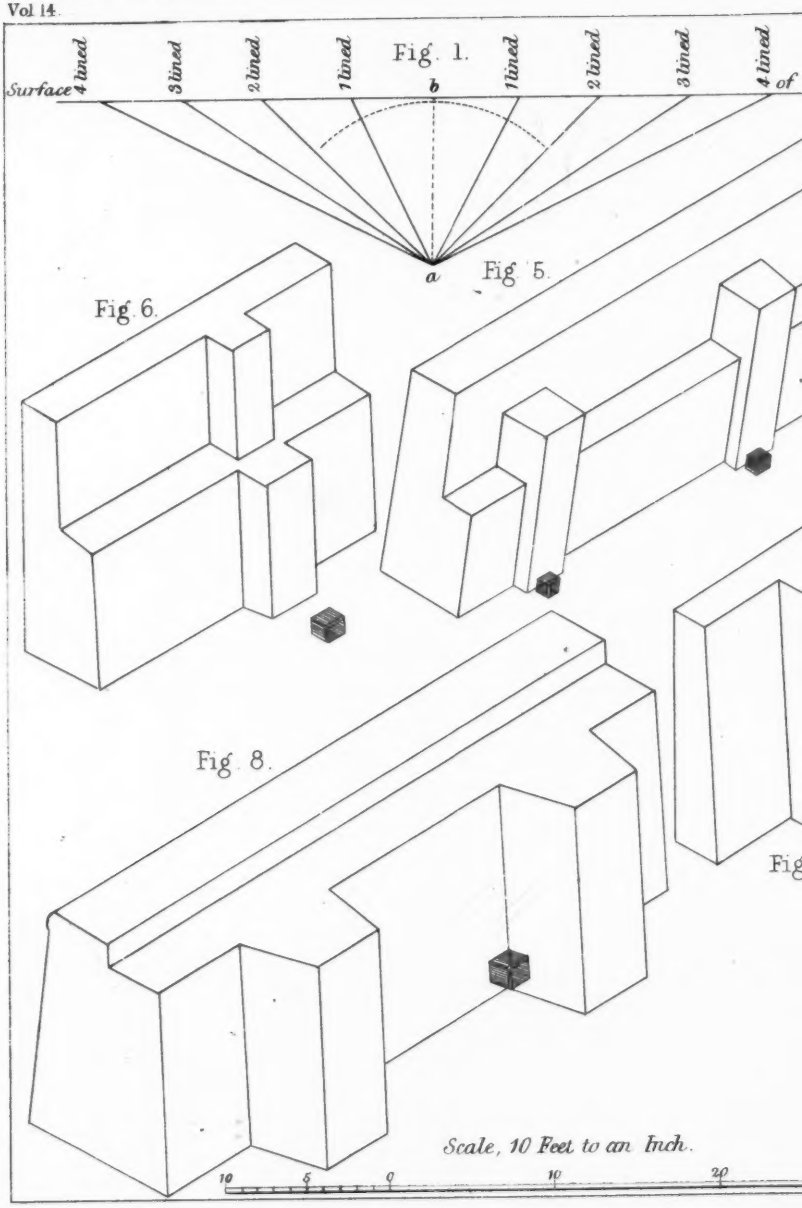


Fig. 1.
Surface
4 lined.
3 lined.
2 lined.
1 lined.
b
1 lined.
2 lined.
3 lined.
4 lined.
of
a
Fig. 5.
Fig. 6.
Fig. 8.
Fig
Scale, 10 Feet to an Inch.
10
5
0
10
20

4 lined.

of Ground

Fig. 2.

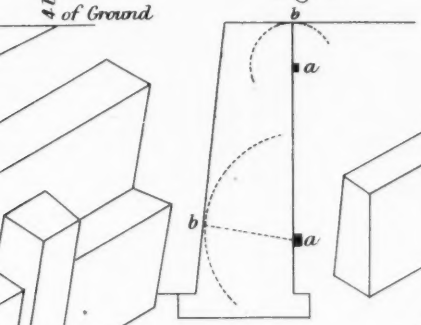


Fig. 3

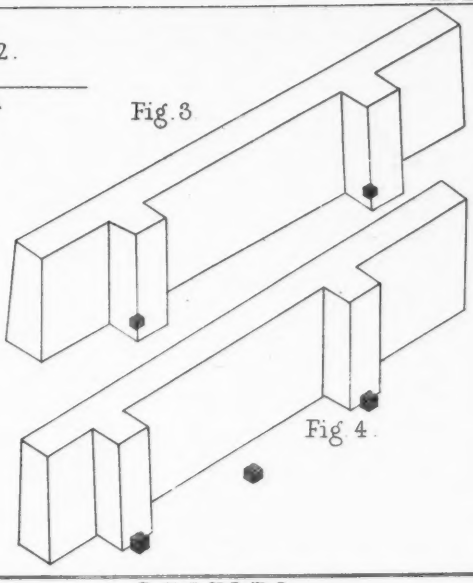


Fig 4.

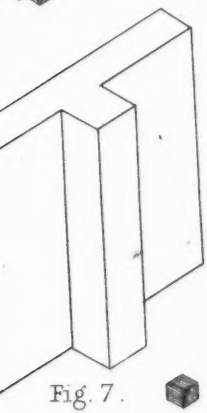


Fig. 7.

RESULTS.

Fig.	L.L.R	Explosive	Charge	LBS	Results.
3	3′ 3″	Gunpowder	¼ L.L.R =	8·5	Complete
		Gun-cotton	1/24 "	1·417	Insufficient
			1/16 "	2·125	D°
			1/8 "	4·25	Equal to Powder
			2/16 "	6·375	Violent
4	4′ 0″	Gunpowder	1/8 "	12·80	Complete
			2/20 "	9·6	
			1/3 "	12·8	
		Gun cotton	1/20 "	3·2	Effect about one half that produced by Gunpowder
			2/40 "	2·4	
			1/20 "	3·2	
5	6′ 6″	Gunpowder	1/3 "	60	Good breach 26′ wide
		Gun-cotton	1/15 "	20	D° 20′ D°
6	8′ 3″	Gun-cotton	1/15 "	37·7	Good breach 27′ wide
7	8′ 1½	Gun-cotton	1/18 "	30	Good breach 28′ 6″ wide
8	8′ 6″	Gunpowder	1/8 "	77	Effect moderate
			2/20 "	92·118	Good breach 16′ wide
		Gun-cotton	3/40 "	46·059	Breach 8′ 6″ wide
			2/20 "	36·807	No Breach 20′
			3/60 "	30·706	Breach 15′ wide
			2/40 "		No Breach

N.B. The walls are shewn as if the earth had been removed from the back down to the level of the charge.

0 80 feet

J. Jobbins

are unfamiliar with the technical terms employed, to offer a few words of explanation.

When a charge is placed in the ground, or in any way buried or confined, the line in which the least resistance would be opposed to the escape of the gas to the surface, is called "the line of least resistance" (LLR). Thus, in each of the cases shown in the sketch, *a* being the charge, *a b* is the line of least resistance (LLR) (Pl. XXIX, figs. 1, 2). As the mass of material thrown out by the explosion of a charge at *a*, would be a solid proportioned to the cube of *a b*, so the charge necessary to effect such a dislodgement of material must also bear a proportion to the cube of *a b*, or LLR^3. In this manner, the charges for mines are calculated, the fraction of LLR^3 varying according to the work required to be done. Thus, in the case of a charge placed in the ground, as at (*a*), in Fig. 1, if it be desired to form a crater of which the diameter should be equal to *a b*, a charge of $\frac{1}{30}$ LLR^3 is found to be necessary. This would be called a "one-lined crater." If a larger crater be required, and it is wished that its diameter should be double *a b*, or a two lined crater, the charge would be made $\frac{1}{10}$ LLR^3, for a three-lined crater $\frac{1}{4}$ LLR^3, and for a four-lined crater 1 LLR^3, and so on. If *a b* were 10 feet, these charges would be 33·3 lbs., 100 lbs., 250 lbs., and 1,000 lbs. respectively.

Where the charge is placed behind a wall, as in Fig. 2, the charge must be increased, and would vary from $\frac{1}{8}$ to $\frac{1}{4}$ LLR^2, according to the nature of the wall, position of the charge, and other circumstances.

It is scarcely necessary to observe that it appears indispensable, after placing the charge, to fill up the hole or opening by means of which its position has been arrived at; this is called "tamping." The tamping should exceed the line of least resistance by one-half, as the filled-in earth will be scarcely so solid as that surrounding. In the case of Fig. 1, the tamping would only equal the LLR if the hole or shaft were sunk direct to the position of the charge. In such cases, it is usual to arrive at the place by means of a shaft sunk at a distance to the required depth, from the foot of which a gallery is driven to the position required.

The line of least resistance is not necessarily the shortest line to the surface of the ground, but that in which lies the least resistance to the egress of the gases generated by the explosion. Napoleon, when besieging Acre, prepared a mine, with which he proposed to blow down the escarp. His engineers were, however, ignorant of the fact that there existed large vaulted chambers at the back of the wall, and unconsciously placed their charge within a few feet of the arched roof of one of these chambers. The result was, that by the force of the explosion the arches were blown in, and an escape being furnished for the gases in the vaults, the escarp was uninjured.

In the system of attack and defence by mines, technically termed military mining, the attacking party frequently wishes to make a large crater, or hole, whilst the defender, with a different object in view, desires to produce a greater effect beneath than upon the surface.

The former may, when an advance by sap is dangerous, mine under the ground in front of him, and having fired his mine and made a large crater, he rushes forward and establishes himself therein, converting it into a portion of his system of trenches. For this purpose, he desires an explosion that will make a good deep crater, which will shelter a good many men whilst working at its conversion.

Again, the besieger suspects or is aware that the besieged has mines underneath the ground over which he is about to approach. He desires to destroy these mines, and accordingly makes mines of his own in front of his trenches, by means of the explosion of which he hopes to destroy the galleries or counter-mines of the besieged. Here, again, though he is desirous of producing a great effect underground, he does not so much care about the crater, but he has no objection to make it, as it may be of use to him, and it loosens the ground for future digging. Should the attacking party eventually succeed in getting a charge placed behind the defenders' walls, the object of the explosion is to make a breach therein, and the larger the opening, the better it will suit his purpose. Thus, as a general rule, the besieger wishes to make a great superficial displacement.

Not so the besieged in all cases. Should the besieger indeed advance and establish himself over one of his mines, he blows it up and loses nothing by the explosion; but when the besieger is further off, and pushing his mines in advance, the besieged in his turn pushes out small galleries from the head of his counter-mines, and seeks to destroy the mines of the attacking party by blowing in his galleries without making a crater on the surface. Thus, it would appear that if two explosive compounds had the qualities, the one of effecting great surface displacement, and the other of great lateral subterranean action, the one might be more suitable for the attack and the other for the defence.

Experience has shown that these two results can be obtained with tolerable certainty with gunpowder by duly arranging the size of the charge and depth beneath the surface at which it is fired, and the dimensions of the crater which will be formed by an explosion of gunpowder may be estimated to within a few feet.

It is found, however, that with gun-cotton fired in the earth, the result is not a uniform crater of conical form like that obtained with gunpowder. A hole indeed is made, but very little earth is lifted or removed, and the craters which have hitherto been formed, would be useless for the purposes for which surface craters are made.

It is a question, whether the lateral underground action of gun-cotton is sufficiently violent to render it valuable for the purpose of destroying counter-mines, and an interesting experiment was tried at Chatham on 14th May, 1870, with a view to gain knowledge on this subject.

Two charges were prepared and placed, one of gunpowder of 500 lbs., calculated at $\frac{1}{10}$ LLR^3, so as to form a crater of 34·2 feet diameter, or a "two-lined crater," and one of compressed gun-cotton of 200 lbs., or $\frac{1}{25}$ LLR^3, being two-fifths the powder charge.

The LLR in each case was 17·1 feet, the charges being at that depth beneath the surface, and the direction of the line vertical.

Shafts having been sunk a distance apart to a corresponding depth, galleries were driven from the bottom of each so as to present a broadside towards the charges at distances of—

From the Powder.	*From the Gun-cotton.*
21′ 0″	21′ 0″
25′ 7″	25′ 7″
29′ 11″ = $\frac{1}{4}$ LLR	29′ 11″ = $\frac{1}{4}$ LLR
34′ 0″.	34′ 0″.

The result of previous experiments led to the belief that the galleries would be injured at a distance of 29′ 11″ or $\frac{1}{4}$ LLR.

The result of the explosion as shown on the surface was, with the powder, a crater of 26′ diameter (it should have been 34′), badly cleared out.

With the gun-cotton the crater was about 23 feet diameter, but the earth not at all cleared out.

The result below was, with the powder, exactly what had been anticipated from former results obtained, viz., that the effect on the casing of all the galleries within 30 feet was such that they would have been perfectly untenable within that distance of the charge. The effect of the gun-cotton charge was fully equal. The injury done to the frames at equal distances being more severe when caused by the cotton than when caused by the gunpowder.

Though the wooden frames were broken and shattered, the earth-walls behind were found to be perfectly uninjured.

There is a property, however, in gun-cotton, when employed in large charges in mining of this description, which would seem to preclude its employment with safety to those using it. The carbonic oxide generated in the explosion is, when mixed with a certain proportion of oxygen, highly inflammable, and should the miners encounter any of this gas when entering their galleries with a light, or in working forward break into a chamber in the earth in which some of it has been imprisoned, fatal results might ensue from an explosion. It is common after firing a large charge of gun-cotton in a confined situation, to hear a succession of small reports thus caused, sometimes lasting over several minutes. The gas, when it escapes freely, is seen to burn in a bright flame over the scene of the explosion.

3. *Demolition of Retaining Walls.*

I shall found what I have to say on this subject upon two series of experiments. The one, made at Chatham in April, 1869, comprising 65 explosions. The other made at Portsmouth in November, 1869, comprising 42 explosions.

In these the main question taken up for solution was the relative power of gunpowder and gun-cotton to overthrow the wall. Other questions, such as tamping, and the best mode of igniting gunpowder,

were touched upon, but to no great extent. The ignition of the gun-cotton was invariably by detonating fuze.

I shall first describe the demolition of a brick retaining wall, forming the escarp of a square redoubt at Chatham. It was 8 feet high and 2 feet thick at top, 2′ 4″ at bottom, with counterforts, 2′ square, and 16′ apart from centre to centre (Pl. XXIX, fig. 3). It was arranged that the charges should be fired in pairs, a sufficient space being left between each pair to prevent the effects produced by the explosion of one pair influencing the result obtained from the explosion of the next pair.

Two charges of 8½ lbs. of gunpowder, ¼ LLR³, ignited by Bickford's fuze, were placed in the centres of counterforts and fired; the effect was good as regards each charge, but the whole of the wall between the charges was not thrown down, owing to the two explosions not being simultaneous.

Charges of cotton of ⅛ of powder-charge were then fired, but the proportion was found to be insufficient, and the wall was not thrown down.

Charges of cotton of ¼ of powder-charge, or $\frac{1}{16}$ LLR³, were next tried, but the effect was less than that produced by the powder-charge. A gun-cotton charge of ⅓ was fired, but the result did not come up to that of the gunpowder.

Effects about equal to those produced with the powder were produced with charges of cotton of one-half the weight of powder. A greater effect, but too violent, with charges of ¾ the weight of powder.

In the next experiment (Pl. XXIX, fig. 4) the two powder charges were placed in rear of the counterforts, instead of within them, and a smaller charge between them, the former, though larger in amount, was less in proportion to the work to be done, being ⅛ LLR³ instead of ¼, as in the last set of experiments; the centre charge was $\frac{3}{20}$ LLR³. The effect was very good.

With charges of cotton of ¼ the weight, or $\frac{1}{20}$ LLR³, the wall between the charges was thrown down, but the breach was only 17 feet wide, whilst that formed by the powder was 32 feet wide.

A pair of charges of gun-cotton of $\frac{5}{12}$ or nearly one-half the gunpowder charge, produced a good result; the breach measuring 28 feet, against 32 feet effected by the powder.

In the next experiment with gunpowder, the centre charge was omitted, the charges in rear of the counterforts being still ¼ LLR³, though the actual amount was increased to 15·4 lbs., owing to the wall being 3 inches thicker, and LLR, 4·3″. A breach of 32 feet wide was made, equal in extent to that made with the three charges, but the demolition was not quite so complete; the amount of powder used was 35·2 lbs. in the first instance, and 30·8 in the second.

With charges of gun-cotton of ¼th the weight, similarly placed, the effect was not so great, a portion of the wall being left standing between the charges. A single charge of cotton of ½ the weight of the powder-charge produced a breach 13 feet wide, equal to the performance of the powder.

The result so far proved that the proportion of ¼ cotton to 1 powder was insufficient; also that when an effect was produced in the imme-

Fig. 1

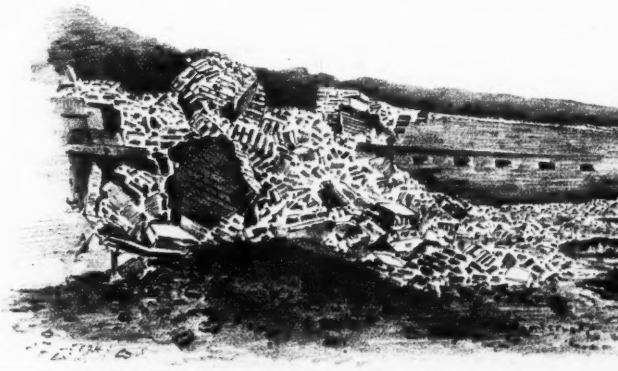


Fig. 2. Gunpowder

2 Charges { LLR = 6'.9"
15 apart { Charges ⅞ LLR³ = 60 lbs

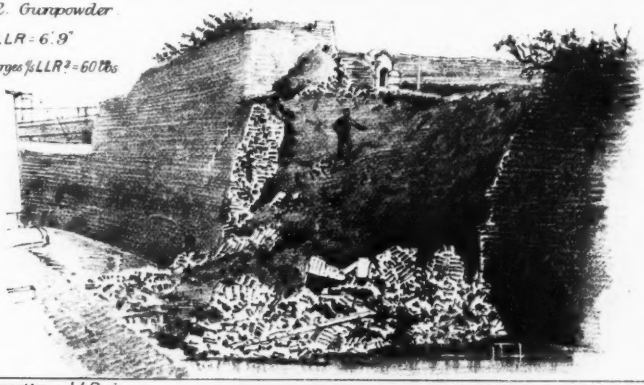
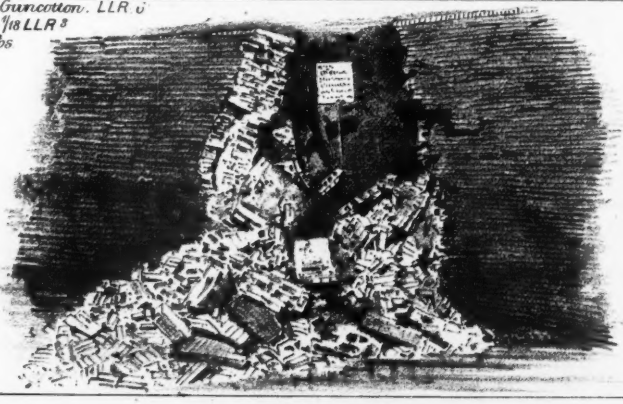
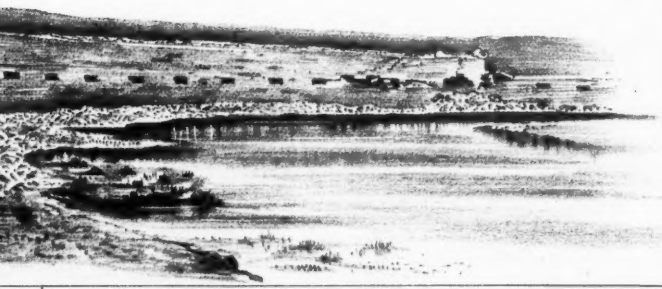


Fig. 4. Guncotton. LLR 5
Charge 1/18 LLR³
= 12 lbs





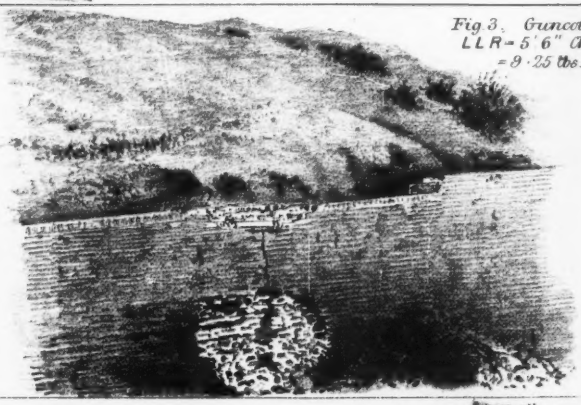


Fig. 3. Guncotton
L L R = 5′ 6″ Charge 1/16 L L R³
= 9·25 lbs.

Fig. 5. Guncotton.
L L R = 8′ 3″
Charge 1/16 L L R³ = 37·7 lbs.

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diate vicinity of the cotton-charge equal to that produced by the powder, the overturning effects caused by the slower explosion of the gunpowder, and which caused the demolition of a considerable extent of wall on either side, was not produced by the cotton.

The next gunpowder standard was calculated at $\frac{1}{5}$ LLR^3 as before, the charges being both placed in rear of the counterforts of a thicker wall, which were 15 feet apart, the LLR being 6·75 feet (Pl. XXIX, fig. 5). The first pair made a good breach 39 feet wide.

A single charge of 60 lbs., fired as above, produced a good breach 26 feet wide (Pl. XXX, fig. 2).

A charge of 20 lbs. gun-cotton, $\frac{1}{15}$ LLR^3, or $\frac{1}{3}$ the powder-charge, was next fired under similar conditions; the bricks were thrown out with great violence, and a breach was formed 20 feet wide.

Two equal charges, one of gun-cotton and one of gunpowder, were next fired simultaneously in the centre of adjoining counterforts as a pair, the charge being 10·75 lbs., calculated at $\frac{1}{4}$ LLR^3, LLR being 3′ 6″.

The breach was 20 feet wide, the portion formed by the powder was more cleared out than that formed by the gun-cotton, the latter appeared to punch a piece out of the wall in front, after which the portion above fell in.

The brickwork of this wall was not good, and it was determined to take a lower standard for the powder. The charge was, therefore, reduced to $\frac{1}{6}$ LLR^3, instead of $\frac{1}{5}$, and two charges of 27·75 lbs. were placed in rear of counterforts with LLR of 5′ 6″, and fired separately. Good breaches were formed in each case of 22′ and 25′ respectively.

Charges of cotton, $\frac{1}{15}$ LLR^3, or 9·25 lbs. (Pl. XXX, fig. 3), were similarly placed and fired, but in neither case was a breach formed, though the wall was much injured, being for a distance of 80 feet in length forced forward, and the bonding with the counterforts being broken.

Dense volumes of white smoke followed the explosion of the second charge, which was attributed to an incomplete detonation of the gun-cotton.

A charge of gun-cotton of 8·5 lbs., similarly calculated at $\frac{1}{15}$ LLR^3 for a rather thinner wall, produced a good breach of 15 feet in clear width.

On these trials being repeated with charges of 8·8 lbs., and 12 lbs. similarly calculated at $\frac{1}{18}$ LLR^3 for walls 5′ 4″ and 6′ thick respectively, breaches were formed from 12 to 17 feet wide (Pl. XXX, fig. 4).

The gunpowder charge was still further reduced to $\frac{1}{8}$ LLR^3, and a charge of 20·75 lbs. being placed at the back of a counterfort, the LLR being 5′ 6″, a very good breach was formed 12 feet in width, about half the width of that formed by the last powder-charges of 12 lbs.

A cotton charge of 10·5 lbs., calculated on the increased scale of $\frac{1}{12}$ LLR, or $\frac{2}{3}$ of the last powder-charge, blew a large hole in the wall 13 feet wide and 5 feet deep, a second explosion of gas, accompanied by a great flame succeeding the explosion. Thus it appeared that the increased charge had a great local effect, without producing a commensurate effect upon the whole of the wall, though it was bulged out

for a length of 23 feet, and there were cracks in the wall for a length of 29 feet, and concentric cracks in the earth behind to a distance of 12 feet.

An intermediate charge of gun-cotton, calculated at $\frac{1}{15}$ LLR^3, was now adopted, and three charges of 4·25 and 8·4 lbs., with LLR^3 of 4′ and 5′, were fired, one in the centre and one in the rear of a counterfort; in each case a hole was made in the wall but no breach. A similar charge of 9·2 lbs. behind a thicker wall made a breach of mean width of 12 feet.

It appeared that the more work the cotton was given to do, the better it acted, and it was resolved to place a charge farther back from the face of the wall, so that the effect might perhaps be more spread, and the likelihood of punching a piece out of the wall might be reduced.

Accordingly a charge was placed two feet in rear of a counterfort, the LLR being 8′ 3″, and the charge at $\frac{1}{15}$ LLR^3 being 37·7 lbs. (Pl. XXX, fig. 5).

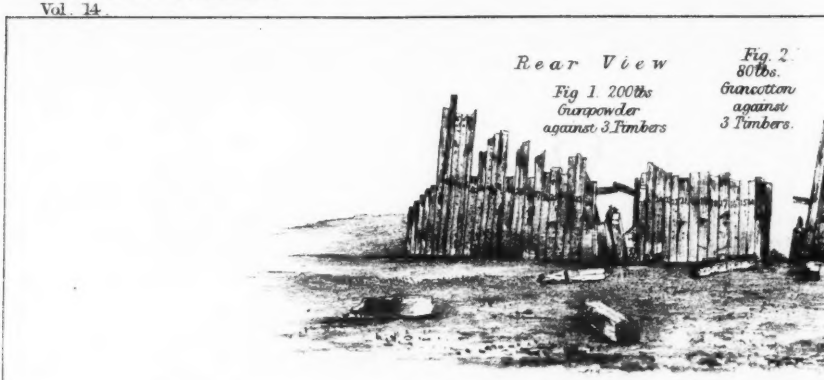
The result of the explosion was a fine breach 24′ wide at top, 27′ at widest part, 16′ high, and extending back 22′ from the top of the wall. The brickwork on each side was much damaged.

This experiment was repeated on a different wall with a charge reduced to $\frac{1}{15}$ LLR^3, the charge being 30 lbs. (Pl. XXIX, fig. 7). The result was a good breach 28′ 9″ wide at top and 18′ 6″ wide at 7 ft. from the top; it extended backwards for 10′ 6″, and was rather more extensive than that formed by double the weight of powder, calculated at $\frac{1}{2}$ LLR^3, the result was, therefore, that the work done by cotton was between three and four times that done by an equal weight of powder; the whole of the wall, for a distance of 13′ 9″ on the left of the charge, being pushed bodily forward 2 inches and pushed away to the left 4 inches.

These Chatham experiments were wound up with a mixed charge of 10·4 lbs. gunpowder and 5·2 lbs. gun-cotton, calculated at $\frac{1}{12}$ and $\frac{1}{24}$ LLR^3 respectively, placed behind a counterfort, LLR being 5′. A good breach was not made, though a hole was blown in the wall 15′ wide by 13′ high, and the brickwork was bulged out for a length of 21′, and otherwise injured.

About six months after the close of the experiments made at Chatham, an opportunity offered for testing the results already obtained in brick walls of inferior quality, by experiments on the masonry revetments of a portion of the fortifications round Portsmouth which were to be destroyed. The walls were of ashlar of Portland stone, backed by rubble of the same material.

The first experiment was to try the resisting power of the wall in comparison with those demolished at Chatham, and a charge, calculated on the lowest scale tried there, viz., $\frac{1}{8}$ LLR^3, was fired in rear of an escarp wall at the angle of junction with the counterforts (Pl. XXIX, fig. 8), the LLR being 8·5 feet, and the charge, 77 lbs. The effect was a complete, but very moderate demolition, not sufficient to be very certain.


Rear View
Fig 1. 200lbs Gunpowder against 3 Timbers
Fig. 2 80lbs. Guncotton against 3 Timbers.

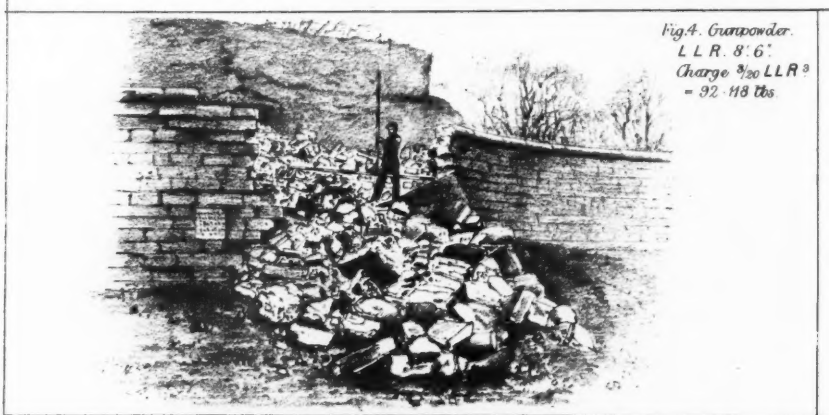


Fig.4. Gunpowder. L L R. 8'.6". Charge 3/20 LLR³ = 92.118 lbs.

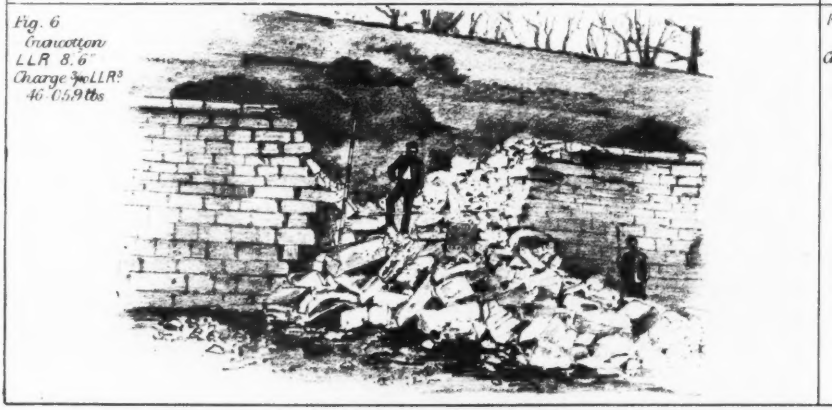
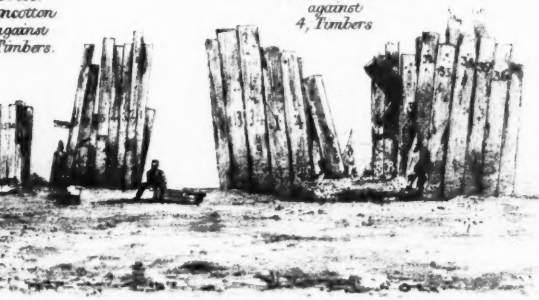


Fig. 6 Guncotton LLR 8.6" Charge 3/20LLR³ 46.059lbs

Fig. 2
80 lbs.
ncotton
gainst
Timbers.

Front view Fig. 3
80 lbs. Guncotton
against
4, Timbers



owder.
6"
80 LLR³
lbs.

Fig. 5.

Combined charge. LLR = 9'.0"
Half powder charge at 1/6 LLR³ = 73 lbs
Half guncotton at 2/26 LLR³ = 29 lbs

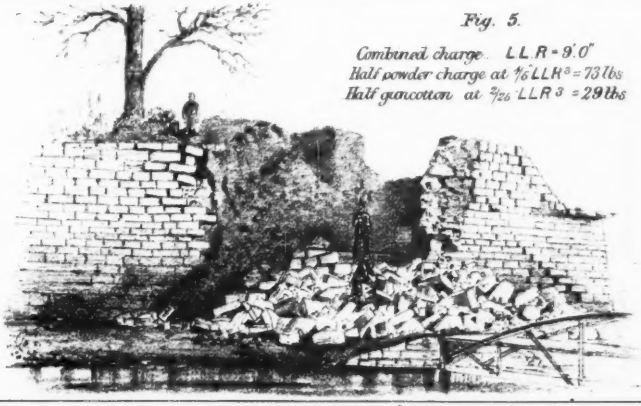


Fig 7. Guncotton
LLR 8'.6"
Charge = 3/50 LLR³
36·847 lbs

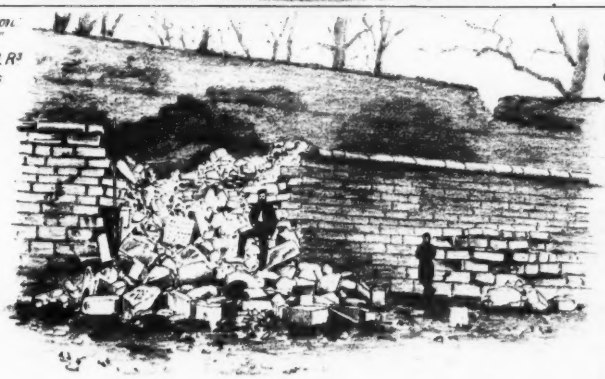


Fig 8.
Guncotton
LLR = 8'.6"
Charge 3/60 LLR³
= 30·701 lbs

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The charge was increased to 92·118 lbs., or $\frac{3}{20}$ LLR³, and the demolition was very good (PL. XXXI., fig. 4). The open breach was 16′ wide, and the wall displaced for 14′ on the left, and 24′ on the right, the latter, however, was the side on which the wall had been shaken by the previous explosion. This proportion of $\frac{3}{20}$ LLR³ was repeated in subsequent experiments on fuzes and tamping, and always gave good results for demolition, but it required a charge of $\frac{1}{5}$ LLR³ to make a breach practicable for assault.

Charges of gun-cotton of 46·059 lbs., 36·847 lbs., and 30·706 lbs., or $\frac{3}{40}$ LLR³, $\frac{3}{50}$ LLR³, and $\frac{3}{60}$ LLR³ were then similarly placed, the largest charge alone produced a breach, which was about equal to that produced by the first charge of powder, $\frac{1}{8}$ LLR³, though the displacement of wall on either side was much greater (PL. XXXI., fig. 6).

The second charge was not properly detonated, and only one stone in front of it was thrown out; the wall, however, was shaken, and cracked considerably.

The third appeared to detonate, but the effect was no greater than the second, the charge being evidently too small (PL. XXXI., fig. 8).

The second proportion, $\frac{3}{50}$ LLR³, was tried again at the back of an escarp wall, the LLR being 7′, and charge, 20·4 lbs. No breach was formed, but the effect was very great. In the front of the wall, slightly above the charge, the stones were pushed forward 10·5″; this extended on the left for 18′, and on the right for 35′, extending for 5′ round the angle of the work. The top of the wall was pushed out from the earth in rear, for a length of 20′ on the left, and 30′ on the right.

This proportion $\frac{3}{50}$ LLR³ being repeated with a greater LLR, viz., 8·5′, and with a proportionately increased charge of 36·847 lbs., made a fair breach 13′ wide (PL. XXXI., fig. 7).

A charge of $\frac{3}{40}$ LLR³, or 46·059 lbs. with the same LLR, made a good breach 20′ wide. The effect being similar to that produced with an equal charge, being the first fired in this series.

The result appears to show that the gun-cotton charge should be $\frac{3}{40}$ LLR³, in order to produce such a breach in the masonry as that obtained with a powder charge of $\frac{1}{5}$ LLR³, or that the gun-cotton charge should be $\frac{3}{5}$ such a gunpowder charge, whereas in the brick walls the best powder charge was $\frac{1}{8}$ LLR³, and the best average gun-cotton charge $\frac{1}{15}$, though in one instance an excellent effect was produced with a gun-cotton charge $\frac{1}{18}$ LLR³. The lateral effect, or the injury done to the portion of the wall adjacent to the breach, is, however, far greater with the gun-cotton than that done by the gunpowder, and it appears that for work of this kind the cotton acts best in large quantities, and that it is desirable to place it so far in rear of the wall as may be consistent with economy, in order that the full effect of the explosion may be given to thrusting out the wall, rather than to violently punching out the portion immediately in front of the charge.

On consideration of these experiments, it appeared that by a combination of the two explosives, a very satisfactory result could be obtained, for by igniting the cotton, and allowing it to ignite the

powder, the cotton would first exercise its power in shattering the wall, the powder with its slower combustion, would complete the work, dislodging and heaving out the *débris*, already loosened by the gun-cotton.

Two combined charges (Pl. XXXI, fig. 5) were fired, in the one case the LLR was 9, and in the other 8·5′, the necessary powder charge was first calculated at $\frac{1}{2}$ LLR^3, and one-half that charge, or 73 lbs. for the greater LLR was taken. An equivalent in gun-cotton, for the remaining half-charge of 73 lbs. gunpowder, calculated at $\frac{2}{5}$ the powder charge, was taken, viz., 29 lbs. gun-cotton; for the lesser LLR, the charges were 61·5 lbs. and 24·5 lbs.; the gun-cotton was put at the back of the wall, the gunpowder behind the cotton, and the latter was ignited by detonating fuze. Excellent practicable breaches were made in each case, the width being 26′ with the larger, and 21·5′ with the smaller charge.

It would be premature at present, on the data which we have, to claim any superiority for the gun-cotton over the gunpowder for works of this nature, for in them there is not the saving in time or labour which gives an advantage to gun-cotton when put into competition with gunpowder for other purposes. Enough, however, has been done to establish a very fair case for the gun-cotton, and to shew the great importance of future experiments when the opportunity occurs. The work done appears to be $\frac{2}{3}$ to $\frac{4}{5}$, the cost $\frac{1}{4}$.

In this, as well as in all other applications of gun-cotton, there is always the same advantage to be claimed for the compressed gun-cotton which it alone holds, distinguishing it from all other such explosives, viz., the freedom from the risk attending accidental explosions from chance sparks or similar causes.

4. *Blasting Walls.*

But few experiments in blasting walls have been made with compressed gun-cotton; the results, however, lead to the inference that gun-cotton charges of $\frac{2}{3}$ths the weight of the powder charge will produce equal results, but it is probable that this is one of the forms in which the gun-cotton least shows its superiority, from the great temptation afforded to a charge placed in the centre of a jointed piece of work, such as a wall, to punch out a portion on either side, and blow a hole through. It is true in this case, as in blasting in rock, that the greater the strength and density of the wall, the more would the gun-cotton gain in the comparison.

5. *Hasty Demolition of Buildings.*

There are times when the rapid demolition of buildings may be necessary, either during the progress of a fire, in order to check the spread of the flames, or after a fire, in order to remove tottering and dangerous walls, or as a military measure, in the case either of destroying an enemy's property of which one is for a short time possessed, or one's own property before abandoning it, in order to prevent its being

of any service to an enemy. It also frequently is necessary in war to demolish a bridge in order to destroy an enemy's communications or to secure a retreat.

When walls are thick, their stability secure, and time and labour are no object, blasting may be resorted to as being economical, for by placing a charge in the centre of a wall, rather than externally on either side, the LLR is reduced by one-half, and as the charges are proportioned to the cube of LLR a great saving is effected in the charge, of whatever it may be composed. A portion of the barrack at Sebastopol, known as the white buildings, was demolished in this manner, and powder thus employed at the rate of 40 lbs. per 100′ in a wall 4′ thick, was more effective than when placed in a trench in charges of 25 lbs. per 10′, or 250 lbs. per 100′, tamped over with the earth taken from the trench, but there have been no comparative experiments made with gun-cotton. It was in these works that the corps of Royal Engineers experienced the loss of one of their most promising officers.

The demolition of these buildings had been entrusted to Major Ranken, R.E., who had only recently received brevet rank for his gallantry in successfully leading the storming party up to the Redan on the day of the assault. The powder hose from four charges had been brought to a focus, which he personally wished to fire. A Bickford's fuze 3′ in length was provided, and it is supposed that in lighting it a spark must have communicated with some loose powder and ignited the powder hose, the whole of the charges went off prematurely, and the walls fell, burying Major Ranken in a mass of ruins. This accident could not possibly have occurred with compressed gun-cotton.

When time and circumstances do not admit of blasting, or when the walls are thin, the explosive may be placed on the ground against the wall, either within or without, in small charges, or a large charge or charges may be placed openly within a building. The former arrangement is more suitable for civil purposes, the latter for the destruction of magazines, casemates, &c.

The barracks at Sebastopol, known as the white buildings, were partially demolished in the former way, and it was found necessary, in order to destroy a 4′ wall, to place powder in 30 lbs. charges 10′ apart, or 300 lbs. per 100′, in a trench against the foot of the wall, each charge being tamped. Fort Nicholas, at the same place, was demolished in the latter way, large charges being placed openly in the casemates, gunpowder, of course, being the explosive employed.

A few experiments have been made with gun-cotton against an 18′ wall, too thin for blasting, of which I will relate the most recent. A portion of wall 5′ long, forming the pier between a door way, and a window of 3′ 6″ in width was selected, a charge of 5 lbs. of gun-cotton in nine discs being placed against the wall edgewise, and occupying a space of 10″ of the wall. The effect was too local, a hole 8′ high and 1′ 9″ wide being punched out of the wall.

A charge of 4 lbs. in eight discs was next tried, the discs being nailed flatwise against the wall and 1″ apart, so as to occupy 2′ 3″ of

the wall. The centre disc was fired, and the wall fell, the brickwork on a level with the charge being completely cut away. The demolition was perfectly quiet and satisfactory.

A charge of 4 lbs. being placed on a board at a distance of 1′ from the wall, and fronting a space of 2′ was fired, there was a loud report, and a great concussion, but the wall was entirely uninjured. A similar charge placed *against* a 5′ pier blew a hole through, the wall tottered for an instant, and then fell. This would appear to be the minimum allowance for such a wall, viz., 4 lbs. per 5′, distributed over about 2′ 6″, or one-half the space to be demolished.

Charges were then fired against a dead wall near a pair of piers of a gateway, 6 lbs. being distributed in the one instance over 5′, and in the other over 4′ 9″, at a height of about 3′ above the ground, and 7′ below the top of the wall. The piers, which were 3′ square and about 9″ from the extreme inner end of either charge, were shattered, but not thrown down. The width of clear hole was in each case about equal to the length occupied by the charge, and 2′ 3″ high, but the wall was cracked through to the top over a length of 8′ from the pier on either side.

A similar charge placed against the ground at a gable end, where there was a height of brickwork of about 20′ above the charge, blew a hole of about equal width, but only 1′ 9″ high, and the wall was not cracked.

The general results lead to the opinion that no known explosive can be safer than gun-cotton for operations of this character. There is no difficulty whatever in applying it, there is no danger incurred in working in, or digging under the walls, and, in the case of a fire, there is no danger of an explosion until the charge is fired in a proper manner by the detonating fuze. In no other known shape can the materials for explosion be so effectually manipulated in small charges. Gunpowder when applied to these purposes, must be employed in larger charges, with risk from the *débris* from the explosion, as well as from the danger incurred in placing the charge, either from fire or from mining under tottering walls. The extreme local action of the gun-cotton in simply cutting or punching out the portion of the wall in its front and vicinity, effects the demolition with the minimum of explosive force. In the instances given above, where gun-cotton was employed, no single charge weighed over half a pound. Further experiments will enable us to determine the punching-charge, and best distribution of the same for walls of various thicknesses.

The next application of gun-cotton is for very hasty demolitions, when it is placed openly in a chamber, as in a casemate, magazine, &c.

A very extraordinary result was derived from an experiment made at Portsmouth in November, 1869, in the demolition of the portion of the old works surrounding Portsmouth.

The part of the works proposed for demolition was a counterscarp gallery of curved form opposite the salient of Townsend Bastion (Pl. XXX., fig. 1). The length of the gallery was 250′, and its width 7 feet.

The front wall was of heavy ashlar, backed with brick, and 5′ thick at springing of arch, and 5′ 9″ at floor level; and it was pierced with 19 loopholes, of which the dimensions were—

Inside.....	5′ 6″	×	10″
At throat	3′ 2″	×	5″
Outside	5′ 0″	×	1′ 6″.

The gallery was arched over from front wall to rear wall, and had a total height of 7′ 4″ inside and 5′ 6″ to springing of arch. The arch was of 120° and 18″ thick.

The earth had been removed from the front half of the gallery, the top of that part of the arch being laid bare.

At either end of the gallery a doorway was provided 6′ high and 2′ 9″ wide, with a wooden door protected on the outside by an iron-grating, composed of bars of 1″ iron, framed so as to be 4″ apart.

A charge of 60 lbs. of cotton was placed within the gallery under the outer haunch of the arch, divided into three portions; each charge occupied 2 feet in length, and the charges were 2 feet apart: therefore the whole charge with intervals occupied 10 feet of the wall, and it was placed between the third and fourth loopholes from the left* end of the gallery.

The charges were fired simultaneously.

From the end nearest which the charge was placed to the 4th loop-hole, or for an extent of about 56 feet, the arch was blown off, and from that point to No. 8 loop-hole, a further distance of about 60 feet, the arch was riven through; the front wall was thrown out from the left extremity of the gallery as far as to No. 4 loop-hole about 54 feet. At No. 5 it was pushed forward 9″, and this displacement came to nothing at No. 10 loop-hole, a total distance of about 141 feet. At this point the damage appeared to be expended for the time, but the striking result was that presented at the right, where the wave of gas generated was *brought up* by the end of the gallery. There the arch was destroyed from the end, back to the 15th loop-hole, about 70 feet. The front wall from the springing level was thrust out 1′ 9″ at No. 19 loop-hole, extending as far as No. 14, about 80 feet, where the displacement ceased. There remained only 97′ of arch uninjured, and 53′ of the front wall.

Perhaps the most striking instance of the wonderfully destructive force of the gas will be afforded by the relation of what it did to the object which afforded it the least resistance.

The door and gate at the left end of the gallery nearest to which the charge was placed, were blown out with violence across the ditch. At the other end, distant from the charge 232 feet, the wooden door had been removed, and the barred gateway alone was closed, the bars presenting to the gas an obstacle of 6 bars of 1″ only in width, to close the opening of 2′ 9″.

One might have supposed, after seeing the immense amount of work done by the charge, that its energy had been somewhat expended, and considering the overthrown walls and arches, that a sufficient

* As viewed from the parapet.

aperture had been formed for the escape of gas. Not so, however: in spite of all that had been done, the force of the gas was not exhausted. Encountering these 6 bars of 1 inch only in width, standing up to oppose its progress, it dashed against them as against the last barrier to its free egress, and not content with hurling them to the other side of the ditch a distance of some 60 yards, rent them and tore them from their frame, bending them and twisting them round and round into the shape of a ram's horn.

The opportunity for another experiment of a similar kind was afforded on the 31st May, when a Martello tower was demolished at Rye. This tower, circular in form, was constructed of brick; the wall on the sea-face was 12 feet thick, whilst on the land side it tapered to 7′ 6″; there was a central shaft 3′ 6″ diameter, from which the covering arch was turned over on to the walls. The arch was 4′ 3″ thick, and covered over with asphalte and concrete. There was a door opening of 6′ × 4′, and two window openings of 3′ × 2′ internal dimensions. The cubical contents of the tower were 7,600 cubic feet. The charge employed was 200 lbs. of compressed gun-cotton, which was divided into three equal portions of 66⅔ lbs. each; one of these was placed on the ground against the thickest portion of the wall, and the two others were placed centrally as regards the floor space, but so arranged as to divide the circumference of the tower equally into three parts. The charges were connected and fired simultaneously by voltaic battery, and the effect was most complete.

The upper portion of the tower with its roof appeared to be gently raised for two feet or so, the walls quietly turned over outwards, and the upper portion came gently to the ground, the pivot still standing erect in its proper position in the centre. There was no loud report, no flame, and not a brick was thrown 50 yards from the spot.

If gunpowder had been employed, it is calculated that a charge of 1,200 lbs. would have been required if thus applied. The lifting and spreading effect of so large a charge of gunpowder would probably have made a more violent demolition, and thrown the *débris* to a great distance. The action of the cotton is very violent so long as it lasts, and it hits a hard blow, but it has not the lifting and spreading effect of gunpowder, which seems to follow up and heave away the *débris* after they have been displaced by the first effects of the explosion.

The best gunpowder demolition with which to compare this was that of Fort Nicholas at Sebastopol by the French, which I have before alluded to.

This was a casemated fort 540 yards in length; one-half of it was composed of three tiers of casemates; the other half consisted of two tiers of casemates, with cellars and magazine underneath. There were also two other large magazines, one on either flank of the fort. The casemates were 39′ long, 20′ wide, and 12′ high to crown of arch, and they were separated by piers 5′ thick. The cubic contents of each

being about 7,600 cubic feet, or as nearly as possible the same as that of the martello tower.

Charges of 2,860 lbs. each, 33 in number, were placed on the floor in the lower story of each alternate casemate, and they were therefore 50 feet apart. Two charges, of 6,600 lbs. each, were placed in the magazines on the flanks, two of 1,540 lbs. each were put in the cellars, and one of 1,300 lbs. in the adjacent magazine, total 106,700 lbs. The demolition was most complete, though there is but little doubt that the quantity of powder employed was excessive.

If gun-cotton had been employed in the same manner and on the same scale as at Rye, this demolition would have been effected with 7,968 lbs. of gun-cotton, or less than $\frac{1}{13}$ of the gunpowder-charge, at rather less than $\frac{1}{8}$ of the cost.

6. *Demolition of Stockades.*

It has been found from experiments on a stockade composed of timbers of a section of 12″ to 14″ cube, ranged in close order, strengthened with a ribband and with butts fixed 3 feet in the ground, that a charge of 40 lbs. of gunpowder, contained in a sand-bag, laid on the ground against the foot of the stockade, and covered over or "tamped" with six sand-bags filled with earth, will, when exploded, form a breach 7 feet in width.

A charge of 60 lbs. untamped, and simply laid against the base of the stockade, will make a breach 5 feet wide.

A charge of 60 lbs. hung against the stockade, 4 feet above the ground, shattered the two timbers against which it was hung, but did not make a practicable breach.

This appears an undesirable way of applying a charge, unless for the sake of destroying a lock or fastening.

Experiments have been made with gun-cotton to compare with these data against a similar stockade, of which the size of the logs was from 12 to 15 inches in section.

10 lbs. of gun-cotton in discs were placed on the ground against three of the timbers. The result of the explosion was, that two timbers and half the third were cut clean through.

The stockade was then strengthened by being backed up by two old 18-pounder iron guns and two pieces of railway iron, and the timbers were fastened together by iron dogs in addition to the connecting ribband.

A charge of 10 lbs. of gun-cotton was placed in a cylindrical tin case 3′ 6″ long and 3½″ diameter, the discs being separated by millboards half-an-inch thick, so as to spread the charge over the length of case. The charge was laid against three 14″ timbers and ignited at one end.

The two timbers on the left were thrown completely over, the third was completely cut through, and only kept up by the ribband.

The corner timber, 15″ in section at the angle of the stockade, strongly supported by the timbers on both sides, was cut clean through by 7½ lbs. of gun-cotton placed against its two outer faces.

One of the timbers forming the stockade was supported on the inside by a bank of earth 4 feet thick, a block of granite weighing 9 cwt., two iron 18-pounder guns, and two iron rails. A charge of 5 lbs. of gun-cotton was fired against this timber, and it was cut three-quarters through, the granite block being driven 1′ 6″ from its position.

The result of all these experiments was held to shew that gun-cotton, employed at the rate of 7 lbs. per foot, would amply suffice to destroy a stockade of the strength experimented upon.

Experiments have since been made with a double stockade, or two stockades, one in rear of the other and 3′ 6″ apart; the timbers being of similar section to those above described, and strengthened with two ribbands.

A charge of 200 lbs. gunpowder, untamped, and contained in four bags was laid on the ground against three contiguous timbers, and fired with a Bickford fuze (Pl. XXXI, fig. 1). The injury extended over 12 feet 2 inches in the front stockade, and 9′ 9″ in the rear. The opening in the front was 8′ 6″. The timbers in the rear were not thrown down. There was no practicable breach.

A charge of 80 lbs. of compressed gun-cotton or two-fifths of the powder charge, was similarly placed and exploded (Pl. XXXI, fig. 2).

A practicable breach was formed, four timbers in the front stockade, and three in the rear, being entirely cut away. The injury extended over 10′ 11″ in the front stockade, and 10′ 4″ in the rear.

The next experiment made was with a similar stockade, the object being to determine whether the charge of 80 lbs. of gun-cotton could, by greater extension, be made to do more work. The charge was laid in a similar manner against the foot of five timbers, or 16 lbs. for each timber of about 15″ dimensions. The result was that the five timbers were cut clean off, and three in the inner stockade were displaced, but not overturned; there was no breach.

A similar charge was then placed in like manner against four timbers, and the result was that these timbers were all cut clean off, the adjoining ones on either side were partially cut through, whilst in the rear stockade four timbers were displaced, two of them being cut clean down, and a breach was made, practicable for men in single file to pass through (Pl. XXXI, fig. 3).

The general result is held to prove, that in order to destroy a single stockade of timbers from 12″ to 16″ in thickness, a charge of 7 lbs. of compressed gun-cotton, per foot of breach, will suffice. And for a double stockade with a 3′ 6″ interval, 25 lbs. per foot of breach.

Thus, to make a 10 foot breach in such a single stockade, a charge of 70 lbs. of gun-cotton would suffice, whilst a charge of at least 120 lbs. of gunpowder untamped would be required: roughly speaking, double the weight.

In the case of a double stockade, 250 lbs. of gun-cotton would suffice, but the gunpowder charge is not determined; it would probably not be less than 500 lbs. In stockades of great strength, the effect of the cotton would probably gain very much over the gunpowder. Loose gunpowder would not be suitable in such a case, it

would probably be tamped. A charge of gun-cotton untamped appears to do as much against a single stockade, as an equal powder charge tamped; and when the weight of tamping is taken into account, together with the exposure of the men required to place it, there can be no doubt of the very great superiority of the compressed gun-cotton over the gunpowder for operations of this description. For very strong structures, it would be impracticable under the circumstances under which such demolitions are usually required, to apply gunpowder, owing to the great weight which would have to be carried over the ground.

7. *Destruction of Wooden Bridges, Piers, Piling, &c.*

Timber bridges or piers may be very rapidly and economically demolished with gun-cotton. A pile 10″ diameter will be completely shattered and broken through by 2 ozs. of gun-cotton, lodged in its centre by means of a hole of 1½″ diameter, bored obliquely into the timber. When time is an object, and a number of holes cannot be bored, such a beam can be completely cut through by a charge of compressed gun-cotton, applied externally.

A pile 17″ by 16″ can be cut cleanly through by a charge of 4 lbs. of gun-cotton, distributed as a collar round three of its sides. In the experiment tried, the discs were 4″ diameter, and 12 in number. The charge, weighing 4 lbs. 2 ozs., was ignited by one fuze between the two centre discs. Charges of from 2¼ lbs. to 2¾ lbs., whether placed all round such a pile, or in a more concentrated order on two sides, failed to do more than cut grooves from 4″ to 8″ deep into the pile, according to the manner in which the charge was distributed.

It is very probable that compressed gun-cotton may be economically used in felling trees, as in clearing forest ground when time is short and labour scarce.

8. *Blasting Rocks under Water, and Demolition of Wrecks.*

Perhaps one of the successful applications of compressed gun-cotton for peaceful objects will prove to be in the removal of sunken rocks or vessels, the pressure of the water under which it will be fired tending to increase very much the effect of the explosion. The compressed gun-cotton is now being used at the Isle of Sombrero for the purpose of blasting rocks of superphosphate of lime under about 20′ to 25′ of water. The charges, which are from 8 lbs. to 10 lbs. weight, are packed in paper, tarred over and placed in any convenient fissure in the rock, the *débris* after the explosion being dredged up.

It has been found impossible to remove entirely the wrecks of sunken *iron* vessels by means of gunpowder. The iron girders which brace and tie together the various portions, whilst they present but little surface to the action of the gunpowder, render such vessels far more difficult to break up than wooden ones: the violent local action of gun-cotton renders it very valuable for this purpose.

The steamer "Foyle" had been run into, and sunk in the Thames

about two miles below Woolwich, in 1866, and several attempts had been made to raise her, but without success; she remained firmly fixed in the mud, and though her back was found to be broken, and attempts were made to raise the two portions separately, she resisted the lifting power of 1,000 tons, breaking the largest chains which could be procured. All that could be cut away and removed by Divers was cleared off, and the Thames Conservancy Board resolved to blow her up, making a commencement with two charges of 120 lbs. each of gunpowder and gun-cotton. One failed to explode and the other did not effect much damage.

Application was made to the War Office, in June, 1868, for the demolition of the wreck by the Royal Engineers, and the execution of the work was entrusted to Lieut. Jekyll, R.E. Three charges of gunpowder of 300 lbs. each were exploded against the after part of the wreck under 38 feet of water, and these made breaches in the side of from 20 to 25 feet in length, but from the dark colour of the water, and the danger attending the diving among the sharp and jagged edges of the iron plates, the amount of injury could not be correctly ascertained. Three smaller charges of 130 lbs. each were then fired on the starboard quarter, and under the stern with good effect, though nothing could be got up. Amidships, where the engines and boiler and machinery were situated, a charge of 300 lbs. of gunpowder was fired in contact with the side of the wreck, but it made no breach whatever, owing to the great resistance encountered in the interior of the vessel. The machinery, however, showed symptoms of having been shaken, and some beams were cracked.

A charge of 230 lbs. of compressed gun-cotton was placed in the same position and fired, and it appeared entirely to complete the demolition. The engines, weighing 300 tons, were shifted bodily out of place; the boilers also were moved, and the wreck was so shattered as to permit of its being pulled up. A dredging-machine without buckets was employed for the purpose, but the operation occupied a year. The total cost of the demolition, exclusive of the dredging, was £189, which includes all labour and materials. The quantity of gunpowder used was 2,000 lbs., costing £55, the gun-cotton was 230 lbs., costing £25. The work done by the cotton was estimated to be equal to that which would have been done with 1,000 lbs. of gunpowder. Therefore, for work done, the cost of the cotton would be rather less than that of the gunpowder, whereas the case for the cotton would be only one-fourth of the bulk of that for the powder equivalent, and a saving in labour would be effected in proportion.

Another opportunity was, in the autumn of 1869, afforded to Lieut. Jekyll, R.E., of testing the value of gun-cotton for demolishing wrecks. The subject this time was a full-rigged wooden ship of 700 tons, named the "Leichardt," which had been run down by a steamer off the Nore in November, 1868, in water of 4½ fathoms at low tide; she lay nearly on an even keel up and down stream, on a bottom of hard mud covered with a thin layer of sand.

For the first three months after she sank, endeavours had been made by Mr. Henry Sykes, who had purchased the wreck as a speculation,

to save some of her cargo by means of Divers, but in that time they succeeded only in getting up one anchor and cable, two coils of rope, and three casks of provisions. The masts of the ship, which had for some time remained standing, were, after a while, together with the bowsprit, carried away by vessels in collision; and in April, 1869, a large vessel, called the "Lord Raglan," cleared away a portion of her starboard quarter. Meanwhile she gradually settled down until there was never less than 2 fathoms of water over her deck.

Mr. Sykes, finding the diving process unremunerative, applied to the Commandant of the School of Military Engineering at Chatham to blow his wreck up for him, hoping to save some of the cargo. Lieut. Jekyll was instructed to inspect her, and he made an estimate for the demolition, which amounted to £175, allowing 800 lbs. of compressed gun-cotton for the purpose. This, however, did not suit Mr. Sykes, who declined to avail himself of the services of the Royal Engineers, surrendering his rights to the Trinity Board.

The Board took immediate steps for the removal of the wreck, and the original project of Lieut. Jekyll was carried out. The gun-cotton was to be divided into ten charges, six of 90 lbs. and four of 60 lbs., and it was intended to arrange five on either side. On the arrival of the first instalment of the gun-cotton, the first five charges were prepared and placed at intervals along one side of the ship, and directly in contact with it, and fired simultaneously by electricity.

The effect is thus described by Lieut. Jekyll:—

"First, a sharp sudden concussion, indicated on the surface by a sort "of shiver and innumerable little jets of water about a yard high, this "was instantly followed by the rise of a huge bank of water, extend- "ing the whole length of the ship and about 30′ in height. As soon "as this had subsided a mass of black mud and discoloured water "came up from the bottom, bringing up broken spars and timbers, "with which the surface soon became thickly strewn.

"Among the *débris* were hundreds of corks bearing the brand of "Coope & Co., the appearance of which was due to a large consign- "ment of bottled beer known to be in the hold; there were also "numbers of candles floating about, some of which were captured and "found to burn remarkably well, in spite of 10 months' immersion. "The timber consisted chiefly of deck planks and other articles of pine "and fir wood; the ship being built of oak and teak, none of the prin- "cipal timbers floated up, being heavy and water-logged. A number "of fish were killed, consisting principally of eels, whiting, and cod, "besides small fry. These floated to the surface and were caught by "the boatmen, numbers of whom had congregated on the spot."

On the next day an examination was made by sounding, from which it appeared that a very considerable amount of injury had been done, and during the three following days a great quantity of timber was washed ashore at Sheerness, Southend, and the Isle of Grain.

As the whole of the balance of the gun-cotton ordered had not been supplied, the demolition had to be suspended for a time, and on the 3rd September, after the wreck had been subjected to the ebb and flow of the spring tides, it was again visited, and a single charge of 90 lbs.

was placed against the stern-post and fired. Soundings taken immediately after shewed that in no place did any portion of the wreck stand more than 3′ above the sand, the depth of water being 4½ fathoms; the wreck was therefore considered to be sufficiently demolished.

The amount of gun-cotton expended was 480 lbs., value £40. The cost of the iron cases to contain the charges was about £15.

A party of Royal Engineers, under the directions of Lieut. Moore, R.E., is at present engaged in the demolition of the wreck of the iron steamer "Golden Fleece," off Sully Island, near Cardiff. Compressed gun-cotton will be employed, as well as gunpowder.

9. *Torpedoes.*

It would appear from what I have said regarding the demolition of wrecks by means of gun-cotton charges, that this substance must be far superior to gunpowder for torpedoes, more especially when employed against iron vessels, and that there could be no doubt as to which would be the best explosive to employ for such work.

This, however, is not so obvious as would at first appear. In the instances cited, the charge has in each case been placed in contact with the vessel against which it has been exploded. We have seen in landworks how very local is the action of gun-cotton, and the question arises how would the vertical and horizontal radii of destructive effect of a torpedo charged with gun-cotton compare with those of a torpedo charged with gunpowder.

The necessity for the consideration of this question arises from the fact that it may frequently happen that a torpedo may, either when fired by judgment, or by the agency of a "circuit closer," be exploded when it is not in actual contact with a ship; and, in order to guard against a failure from such a cause, it is desirable to have some rule by which to determine the distance at which a given charge would exercise a destructive effect upon a vessel.

It has been found, from a series of experiments conducted at Chatham with small charges, against a swinging wooden target under water, that whatever effect may be produced by a given charge of gunpowder against a target at a distance, the centre being at the same depth below the surface as the charge, an effect at least equal, if not greater is obtained by a charge of compressed gun-cotton, of one-fourth the weight.

These experiments have been supplemented by others, in which the measure of lateral effect produced has been estimated by the radius of the crater formed in the mud by the explosion of a charge placed on it at certain distances below the surface. It has appeared from these that a greater crater is usually formed by a given charge of gunpowder than by its equivalent of gun-cotton of one-fourth the weight, owing to the slower combustion of the powder, which allows of the water surrounding the charge getting up a motion to find room for the gases generated, whilst from the more rapid combustion of the gun-cotton, the horizontal effect, as measured by the crater, does not extend

so far, the column of water, however, is projected upwards with a greater force; the amount of injury done within the respective radii being greater with the compressed gun-cotton than with a powder charge of four times the weight. If the vessel should be directly above the charge, a greater effect would undoubtedly be produced by the gun-cotton than by the equivalent gunpowder charge.

It is observed, that when a considerable charge of gunpowder is exploded in deep water, the column raised is composed of "green water," the slow combustion of the powder allowing the water to be raised in a mass above the surface, in order to afford a vent for the gases. With gun-cotton, however, the column is composed of "white water," the rapid combustion of the charge instantaneously developing the gases which race to the surface through the water before time can be afforded for any great lateral displacement of the water surrounding the charge. It is estimated that, as regards the lateral or horizontal destructive effect, equal radii would be obtained with a charge of gun-cotton of two-fifths the gunpowder charge, the actual damage done within that radius being, however, greater in the case of the gun-cotton than in that of the gunpowder, as appeared to be the case in the "Military Mines."

There is another point that is important. A charge of gun-cotton calculated to do the same work as a given charge of gunpowder would occupy only one-fourth to two-fifths of the space; the cost of the torpedo, therefore, would be reduced in proportion, as also the labour in handling, fixing, or mooring it, also the space required for storing torpedoes. Again, if it were required to employ "buoyant" torpedoes, the amount of buoyancy, or buoy power, required to keep them in place, would similarly favour the employment of the gun-cotton charge.

The foregoing remarks will serve to illustrate the essential qualities of this compressed gun-cotton. It is not likely at present to supersede gunpowder for some of the purposes for which gunpowder has had a pre-eminence for so many years; but for engineering purposes it appears that, thanks to the great intelligence which has been brought to bear upon it, in the first invention of the wet or pulpy manufacture, due to Mr. Abel, in the details of the manufacture carried out by Mr. Prentice, and in that very essential discovery regarding the power of the detonating fuze, which we owe to Mr. Brown, gun-cotton has, in a very few years, been brought from a state in which it was almost considered hopeless, to one in which it can fairly compete with gunpowder in every respect, and favourably in all but artillery work. Last, but not least, we gain, wherever it is made or employed, the inestimable advantage that those who are engaged in its manufacture or in its use are not daily treading on the verge of a volcano, their lives and those of all within reach, depending upon so slight a contingency as a spark from a chimney, an ash from a pipe, a match head on the ground, a nail in a boot, or a grain of grit on the floor. This alone is sufficient to give it a very great superiority over any explosive which has as yet been made.

LECTURE.

Friday, 24th June, 1870.

MAJOR-GENERAL D. RUSSELL, C.B., in the Chair.

SHELTER TRENCHES, OR TEMPORARY COVER FOR TROOPS IN POSITION.

By Colonel GERALD GRAHAM, V.C., C.B., R.E.

SHELTER-TRENCHES (tranchées-abris) may be considered a rapid application of field fortification for temporary purposes. They may be defined as having rather the character of offensive than of defensive fortification, resembling in their functions more the besiegers' parallels, or "places of arms" than intrenchments for the defence of a position, but they must always be considered as supplementary to natural cover and not as a substitute for it. In fact, as the title of this paper indicates, the primary object of "shelter trenches" is to obtain cover for troops in a given position, without interfering with their advance when required. Yet shelter-trenches may be combined with more purely defensive works, as when occupying the intervals between detached works, or portions of them may be converted into intrenchments, therefore they cannot be dissociated from field fortification, in fact they come under the general heading of temporary field fortifications.

Field fortification is perhaps the oldest art in existence, an art probably coeval with the history of man—that is with the history of war, and indeed our oldest records bear witness to its antiquity, whether graven on the granite of Egypt, or mirrored in the customs of contemporary savage nations. What changes have taken place since the Assyrian king "cast a bank against the fenced cities of Judah," * and yet even now a general of an army, equipped and furnished with the latest results of science would, like Sennacherib, "cast a bank" against a modern fortress.

Fortification may, for our purpose, be sufficiently accurately defined as the art of protecting combatants while preserving their fighting powers, and thus, by lessening their adversaries' capacity to inflict injury, it strengthens, or fortifies, the side that employs it. Being

* He shall not come into this city, nor shoot an arrow there, nor come before it with shields, nor cast a bank against it.—Isaiah, xxxvii, 33.

stationary, fortification is now usually considered defensive, being thus necessarily employed by that side which awaits attack, generally (though not always) the weaker side. The attack, however, now, as in old times, employs fortification to combat fortification, and is perpetually striving to produce some movable defence for aggressive purposes, such as of old were the shields of the ancients, the wooden towers that were wheeled up to the walls of the besieged fortress, or the towers mounted on elephants, and the war-chariots armed with scythes. These latter were really movable forts, from which a formidable plunging fire of missiles could be delivered at any required point of the battle. Several chariots in line would also make a formidable obstacle analogous to a modern street barricade, with the advantage of being able to advance, or retire, as required. Later came the Pavésades, a line of shields, each shield or pavois serving to cover two men, one of whom held it whilst the other fought, or the whole line advanced under cover. The heavy armour of the middle ages may be said to have converted each knight into a fort,* while those who fought on foot protected themselves with shields or targets.

These old devices for protection are ever re-appearing with new faces, and portable fortifications are constantly being recommended for adoption in some form or other. Thus the war-chariots of the early Greeks and Assyrians may be considered the prototypes of the iron-plated railway battery; the wooden towers and "pavésade," of the movable steel mantlets (so ably advocated in this room not long ago),† and the missile-catching shields of the musket-proof knapsack,‡ which has also its supporters both at home and abroad. (See Appendix 1.)

Yet we engineers, as a body, like those of old, prefer going to our mother earth for aid and protection, and to "cast a bank" with a simple spade, rather than rely on more cumbrous defences. It was in moving earth that the Roman legions conquered the world, and although our ambition is limited to holding our own, we shall do well to take a lesson from those grand old pagan soldiers, "to whom," in the language of Gibbon, "the use of the spade and pickaxe was no less "familiar than that of the sword or pilum. Active valour may often "be the present of nature, but such patient diligence can be the fruit "only of habit and discipline."—("Decline and Fall," &c.)

In the wars of the middle ages, Charles V and the Prince of Parma appear first to have restored field fortification to its due prominence in tactics. Charles V attached to each regiment of Landsknechts a company of pioneers of 400 men. This company, placed under the command of a special officer, carried with it a little pack of tools, and in

* It was not until the commencement of the 18th century that defensive armour for infantry was entirely abolished in France.—G. G.

† See "Journal of the Royal United Service Institution," No. lv., page 326, vol. xiii.

‡ This is, I believe, the only *personal* portable defence advocated, with exception of an invention by a Signor Muratori, of Turin, described as a cuirass of cloth or canvas (which has previously been treated with some preparation). This cuirass is reported to resist easily a powerful bayonet thrust or revolver bullet fired at half-a-dozen paces. (Report of a Professional Tour of Officers of Royal Artillery in 1868). —G. G.

fact corresponded to our present Royal Engineer train. The Prince of Parma had a similar organization, and his army numbered 3,000 pioneers, who were reinforced as required by workmen taken from the infantry.* Colonel Brialmont states that since the time of the Prince of Parma's famous siege operations, the custom of having troops specially entrusted with the execution of field-works seems to have fallen into disuse, such works, in the subsequent wars of the Princes of Nassau, Gustavus Adolphus, Louis XIII and XIV, being the forced or voluntary work of the country people. "Historians agree that soldiers "objected to the use of intrenching tools, notwithstanding the laudable "efforts made by their leaders and sovereigns to overcome this preju-"dice."† Our own army in the Peninsula was strongly affected with this feeling, thus Sir John Burgoyne, in his "Military Opinions" (p. 286), says:—

"Works are not executed by the British in the time they should be, "nor with the alacrity with which they are in other services. I have "known our men (the line) refuse to take out their gabions and set to "work. I have myself placed, at different times, hundreds of gabions "with my own hands, and then *entreated* the men to go and fill them, "but to no purpose."

"In short," says Sir Francis Head, "in the Peninsula these noble "fellows trained to fight in the open, like the generals who commanded "them, disdained either to seek or make cover of any sort."‡

A good deal of this feeling still lingered among our soldiers of the Crimea, but now it is fast dying out, and, with more instruction, we may hope to see it altogether disappear. We have good grounds for believing this when we note the gallant spirit with which the 2nd battalion of the Scots Fusileer Guards devoted themselves to field-works in the Tower ditch last summer, voluntarily and without any remuneration. When we see such a distinguished corps as this take up the spade and show intelligent interest in their works, we may consider that the time has passed away when our Army, like Gallio, "cared for none of these things."

In the highly disciplined Army of Frederick the Great, (long our model for drill) the soldiers had to work when required, like the Roman legionaries. At Bunzelwitz, for instance (20th August, 1761), for three days and nights one half his army (25,000 men) were constantly at work; but it would trespass far beyond the limits of this paper to narrate the many instances when intrenchments rapidly thrown up on the eve of action, have changed the fates of campaigns, and perhaps of nations. This is attested in the Seven Years' War by the fields of Reichenberg, Kunersdorf, and the camp of Bunzelwitz; later by Jemappes, Fleurus, Caldiero and Borodino. It is sufficient to note that all the greatest Captains of modern times, Turenne,§ Saxe, Frederick the Great, Napoleon, and (as far as his means permitted) the

* "La Fortification Improvisée," par A. Brialmont.

† Idem.

‡ "The Royal Engineer," by the Right Hon. Sir F. B. Head, p. 350.

§ Turenne rarely neglected to fortify his camp, covering it by small detached works, furnished with abatis, &c. These works (very similar to shelter-trenches), for

Duke of Wellington, have declared and testified for all time their sense of the value of fortification in the field. "Field-works," said Napoleon at St. Helena, "are always useful, never injurious (nuisibles) when "well understood."* Our own history illustrates this fact as well as any other. Thus, at a very early period two of our proudest victories were gained with the aid of intrenchments. At the battle of Crecy, August 25th, 1346, Edward III. threw up trenches on his flanks and intrenched his baggage (Foissart, chap. 126, Hume, vol. ii.). At Poitiers (Sept. 20th, 1356) where 12,000 English stood opposed to 60,000 French, the Black Prince strengthened his well chosen position by intrenchments during the night before the battle (Froissart, chap. 160, Hume, vol. ii.). Since the days of Crecy and Poitiers, our records of intrenchments used in battle are scantier than those of Continental nations. Yet we must remember the great lines of Torres Vedras, before which Massena (Napoleon's spoilt child of victory) vainly chafed and fretted away his strength; the intrenchments of Fuentes d'Onoro, thrown up in presence of the enemy, by which the same general was again foiled in his purpose; the central redoubt at Talavera,† where Campbell successfully repulsed the French attack; also Hougomont and La Haie Sainte at Waterloo.

Yet these are only noted occasions where field-works have had a direct undeniable influence on actions, but how many cases must there have been where temporary fortifications, such as bridge-heads, intrenched outposts, and works of lesser importance may have indirectly contributed largely to influence the operations of the campaign, although unnoted and unknown by the military historian, and perhaps by the Army in general!

Sir William Reid, for example, in a valuable paper "On Intrench-"ments as supports in battle" (Professional papers, R.E., vol. 2, old series) mentions an officer of the 52nd Regiment who, being in charge of an outpost during the operations of the passage of the Nive in 1813, fortified it so well that the pickets had no occasion to retire until they had fired their 60 rounds of ammunition. "Thus the troops for the "defence of the main central position had full time to assemble (for it "was December, and they were scattered in houses) and to deploy in "the position," &c.

Since 1815, intrenchments skilfully planned, appear to have weighed heavily in the scales of victory. Witness the Austrians, who made great use of intrenchments against the Italians in 1848, but none at all against the French in 1859, and who again in 1866 at the fatal field of Königrätz, made little or no attempt to strengthen the villages in front of their line (Sadowa, Dohalitz, &c.). "The entrances," says Capt. Webber,‡ R.E., "were not even closed; and the strong stone

his first line of infantry, took only a short time to complete. His tools were carried on the crupper by dragoons. ("La Fortification Improvisée.")—G. G.

* "Montholon," vol. i, pp. 248, 249.

† See "Wellington's Despatches," vol. iv, p. 50; also Sir J. Jones's account. No mention of this redoubt by Sir W. Napier.—G. G.

‡ "Notes on the Campaign in Bohemia," by Captain Webber, R.E. Professional Papers, R.E., vol. xvi.

"buildings which were quite capable of resisting field artillery, not "even loopholed." The defences of Chlum extended only to the north and north-west sides, while the Crown Prince attacked it on the north-east side. Yet incomplete as they were, the Austrian intrenchments were of great use to them. The Prussians, although attacking, did not neglect the use of field-works, as shown by the strong intrenchments of Dresden, and the defences of Pardubitz.* In the American War, each side made the greatest possible use of intrenchments. Each brigade intrenched itself at the end of the day's march before even cooking their rations. At New Hope Church, writes Sherman, reporting on the Atlanta campaign, the enemy was repulsed, but having hastily thrown up some intrenchments he maintained himself in his position, and next day we found him strongly intrenched; thus our attack was fruitless. At Dallas, on the other hand, the Southerners' assault was repulsed, owing to the intrenchments made by Sherman's troops.†

It is noteworthy that the experience the Americans gained in their three years' fighting led them to multiply intrenchments with great rapidity towards the latter end of the war, as is shown by the battles of March, 1865, round Petersburgh, when the same troops threw up successive lines of trenches during action. Quoting the statement of a Federal Officer:—

"Twice had I to change my position in the course of an hour, and "each time I left behind me a nearly finished line of intrenchments, "so much skill and agility had my men acquired in this kind of "work." ("Four Years' Campaigning in the Army of the Potomac," by a Federal Officer.)

This great American contest proved the advantage of cover in all field operations, and the later Bohemian campaign of 1866, by displaying the startling effect of the breech-loading rifle, made it obvious that, in future warfare, troops will have to be kept under cover as much as possible, whether acting on the offensive or defensive.

Marshal Bugeaud said, "If the time for fighting has not arrived, keep yourself out of range, or cover your troops." Had this been written in the era of rifled guns and small arms, he would have omitted the former alternative, which is obviously incompatible with any intention of sudden attack, and deliberate advance under fire from long range is no longer to be thought of.

With the evidence of this before them, the object of the leading military powers of the Continent became to adopt a method of intrenchment offering extreme facility of execution, and no obstacle to advance, so that it might, by rapid successive formations, where required, as much as possible realize the principle of movable attacking fortification, without the disadvantages attending all *portable* fortifications hitherto proposed.‡

* Capt. Webber estimates the length of line in these defences at 3½ miles. They were to be held by 1,500 infantry and 24 guns.

† I have quoted this at second-hand from Col. Brialmont, not having the originals. A great many interesting extracts are also given by Sir F. Head ("The Royal Engineer," pp. 330–335).—G. G.

‡ Il en est résulté une fortification volante qui ne constitue pas un obstacle, mais

Besides these general principles, the consideration of many important details tended to force to the same conclusion; thus, it became evident that, by the introduction of the breech-loading rifle, a soldier in action can obtain cover, where before he would have been insufficiently protected; as, with this arm, he can load while lying at full length on the ground, without changing the horizontal position of his piece, or betraying himself by any movement. In this position, besides being covered, he has the advantage of being able to see an advancing enemy, while the latter can see nothing but smoke, and of firing with at least five times the rapidity of the muzzle-loading rifle, and with much greater accuracy, having a rest for his piece on the parapet. While furnished with this prodigiously destructive power, the soldier in the shelter trench will be protected against the fire of infantry, and to a great extent, against that of artillery, as we shall see in considering the results of the experiments at Dartmoor last year.

In order to put more clearly before you the opinions of foreign military authorities, I will briefly allude to some late regulations and operations in France and Austria.

To begin with the latter: at the opening of their disastrous seven weeks' war, the directions of Benedek to his troops were, to "avoid "standing still before the Prussian lines, oppose their defensive fire "by keeping in motion, and charge as soon as you get within 200 "or 300 paces." Since 1866, their military reviews enunciate the doctrine that "the tactics of the future will be entirely confined to "battles of position and firing." ("Tactique de l'Infanterie," by Captain Pontus.) A great variety of intrenchments have been designed and tried by the Austrian military authorities in accordance with this view.*

The following is an extract from instructions published by the French Minister of War in 1867:—

"Les bataillons de la première ligne, déployés et couverts, s'il est "possible, par des plis de terrain, par des abris, par des tranchées, "attendent que l'ennemi soit arrivé à bonne portée pour l'écraser par "des feux en masse, surtout au moment de la formation des colonnes "d'attaque et lorsque ces colonnes se portent en avant sur la position. ". . . Aborder de front, en terrain decouvert, une infanterie non "entamée, surtout si elle est protégée par des obstacles ou des couverts, "a toujours été une opération dangereuse; aujourd'hui surtout, avec "les armes nouvelles, l'avantage appartient à la défense.

"Une troupe ayant à parcourir 300 à 400 mètres, sous un feu "écrasant, quelque brave qu'elle soit, se trouverait exposée à être "détruite avant d'avoir atteint le point décisif de l'action et dans tous "les cas arriverait trop affaiblie pour lutter avec succès contre un

un abri pour les hommes.—(Fortification passagère, M. T. Prevost, Chef de Bataillon du Génie.)

* It is needless to say that this principle may be carried too far, and result in a loss of all power of manœuvring; but it may safely be asserted that in future no bayonet charge should be attempted against troops in position, unless they have been previously disorganized by fire, in which case the charge would complete the advantage obtained by the fire.—G. G.

" ennemi preparé à la recevoir et qui au dernier moment prendrait " l'offensive."

Colonel Brialmont relates that, after the American war, the French made a trial of rapid intrenchments at Châlons. "Later on a field day at Vincennes, a division of infantry got orders to intrench themselves in presence of the enemy. The operation was protected by a cloud of skirmishers. About one-third the effective strength of each battalion got tools. In less than half an hour the whole division was under cover in well made trenches. This experiment was considered very conclusive (très concluante)."*

We thus see what is the opinion of those in authority in the leading military nations, but it is well that we should pause to consider how far the reasons that have guided them should affect us, who have our own method of fighting, which cannot be abandoned in mere deference to foreign authority. To do this, we must first glance at the progress that has been made in artillery and infantry-fire since our last European war.

In the Crimea, we were opposed by no arms of precision, except those used by sharpshooters from the Russian rifle-pits, so that we must gather our notions of the effect of rifled artillery from foreign experience in war, and from our own experiments. By comparison of results obtained, it may be roughly stated that where one shot struck before the introduction of rifled cannon, twenty would strike now at ordinary effective ranges (see Appendix No. 2); but this is far from stating the difference between the rifled and smooth bored guns in their relative effects on bodies of troops. A series of very valuable experiments was carried on at Dartmoor last year for the purpose of ascertaining the effect of different kind of shell on targets representing infantry in various formations.

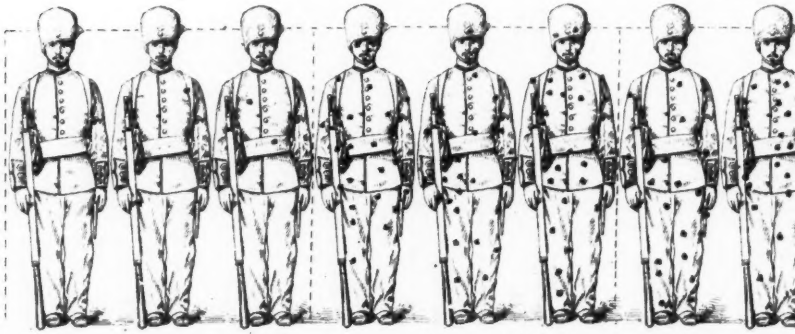
The diagram on Plate XXXII, shows the number of hits produced by 15 rounds of 12-pounder rifled segment shells, at 1,000 yards, on 15 men in single rank, standing, kneeling, and in shelter trench.†

It would have been better, had time permitted, to have had the results noted at the end of each round, as it is, I cannot give any correct statement of killed and wounded from this diagram, many having been killed and wounded several times over. Thus numbers 4 and 5 of this diagram have received 25 hits each, the total number of hits being 196. As might be expected, the effect of shell on columns is much more remarkable; thus in experiment No. 13, at Dartmoor, 15 rounds of 12-pounder segment shells (with E. time and C.F.S. percussion fuze) were fired against targets representing 6 companies of 27 file each, drawn up at quarter distance behind a slope, so that only the top of the front row was visible. At a range of 1,700 yards, this column was struck in nearly 1,000 places (949 hits). Another experiment (No. 31) was tried on a similar column, partly retired behind the crest of a hill, at 1,670 yards with the same shell (C.F.S. percus-

* "La Fortification Improvisée," pp. 16 to 19.

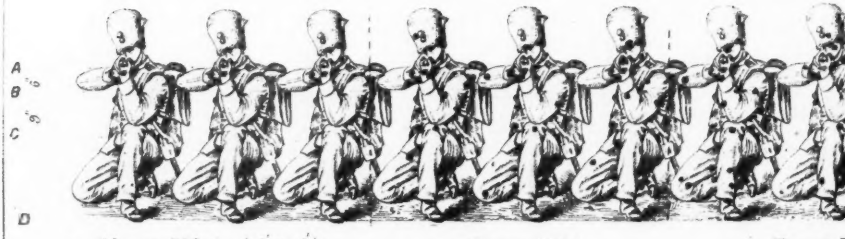
† The hits were copied off the official diagrams, kindly lent me by Captain Alderson, R.A.

Results of Practice with 15 rounds of 12 Pr. Se
Corresponding to 5 Darts
Fig. 1. Stan



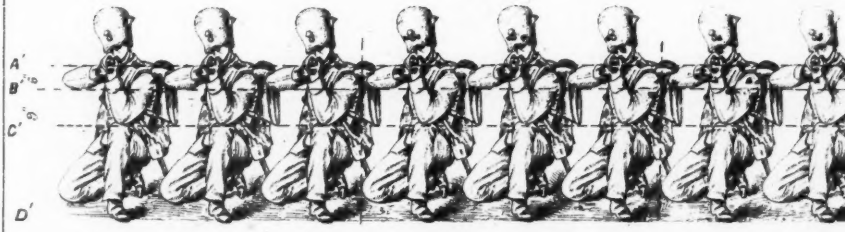
Target N°. 4. (6 × 6) Target N°. 5 Target

Fig. 2. K



Target N°. 4. (6 × 6) Target N°. 5 Target

Fig. 3. In Shel

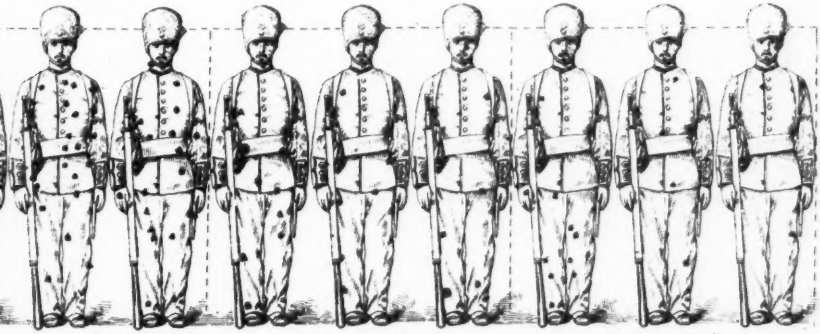


Target N°. 4. (6 × 6) Target N°. 5 Target

In Fig. 3 level of ground (i.e. of bottom of target) is 15 inches below A'A', the
with C'C'. Fig. 3. Between A'B' "throughs" only count, between B'C' only whole shel

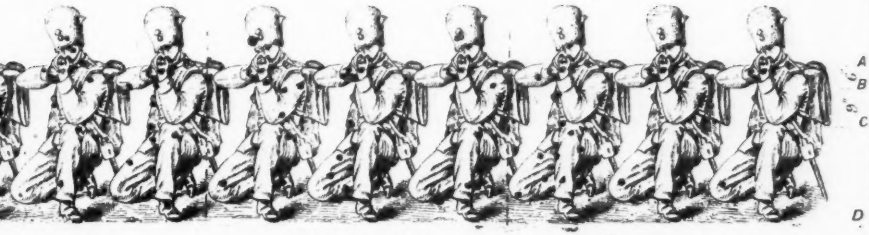
The Dots on the Figures shew the hits with 15 rounds of 12 Pr. segment shell at 1000 yards on targets

2 Pr Segment shell on a single rank of 15 men
s Dartmoor Targets 6' x 6'
g 1. Standing.



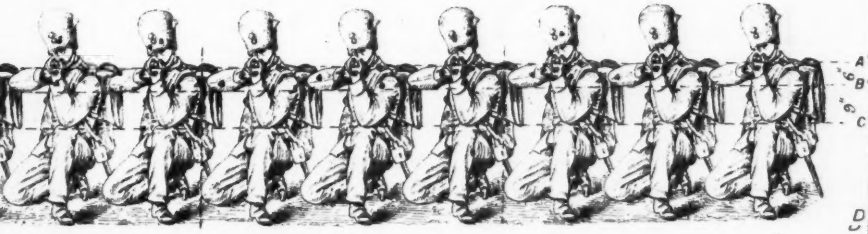
Target N° 6. *Target N° 7.* *Target N° 8*

Fig. 2. Kneeling



Target N° 6. *Target N° 7.* *Target N° 8.*

. In Shelter Trench



Target N° 6. *Target N° 7.* *Target N° 8.*

A'A', the level of top of parapet. D.D. therefore in Fig 2 corresponds in level
whole shell, & between C.D. (being below ground level) the men are entirely protected.

s on targets 4 to 8 obtained by Exp.s N° 4 at Dartmoor. N° of hits standing 196. kneeling 109 in trench 36.

J. Johns

sion fuze), and this time with 15 rounds, the column was struck nearly 1,200 times (1,194 hits).

This alone should be sufficient to convince us that troops can no longer be exposed to artillery fire within effective range of segment or shrapnel without cover.

Turning from artillery to small arms, we find the progress in the science of destruction since our last European war, even more astonishing. In order to assist us in estimating the difference between the arms of the smooth-bore period and the latest breech-loaders, I will quote the following extract from the text-book in use at the School of Musketry (p. 110, et seq.) :—

" The shooting powers of the percussion musket, 1842, are shown " in a report on 'Experimental Musketry Firing,' carried on by Captain " McKerlie, of the Royal Engineers, at Chatham, in 1846, which con- " cludes as follows :—

" ' It appears by these experiments that, as a general rule, musketry " ' fire should never be opened beyond 150 yards, and certainly not " ' exceeding 200 yards. At this distance, half the number of shots " ' missed the target, 11 feet 6 inches, and at 150 yards, a very large " ' proportion also missed; at 75 and 100 yards every shot struck the " ' target 2 feet wide, and had the deviation increased simply as the " ' distance, every shot ought to have struck the target 6 feet wide, " ' at 200 yards; instead of this, however, some were observed to pass " ' several yards to the right or left; some to fall 30 yards short, and " ' others to pass as much beyond; and the deviation increased in a " ' still greater degree as the range increased. It is only then under " ' peculiar circumstances, such as when it may be desirable to bring a " ' fire on field artillery, when there are no other means of replying to it, " ' that it ought ever to be thought of using the musket at such dis- " ' tances as 400 yards.' "

After the interesting paper read here, and published in the Journal of this Institution (The Martini-Henry Rifle, by Capt. V. D. Majendie, R.A., No. lv, Journal of Royal United Service Institution), it is unnecessary for me to say much about breech-loaders, but it is curious to compare these records of Old Brown Bess with some of the achievements of that latest, deadliest combination, the Martini-Henry. Captain Majendie gives the following as averages of 5 targets of 20 shots each with this arm :—

At 300	yards,	mean	deviation	..	·57 feet
500	"	"	"	..	·95 "
800	"	"	"	..	1·63 "
1,000	"	"	"	..	2·80 "
1,200	"	"	"	..	3·46 "

As regards rapidity, a rate of fire, without aiming, of 20 rounds in 48 seconds, equal to 25 shots a minute, has been obtained.

This will make battles somewhat different to what they were when a man was safe at 200 yards, and when, as military writers have estimated, not more than 1 ball in 10,000 attained its mark, though of course the practice of the rifle range is not that of the battle field,

where allowance must be made for haste and excitement, exaggeration of distances, &c. More experiments, especially in volley firing, which the tactics of the day prescribe for breech-loaders, will have to be made before the relative value of the Martini-Henry to its predecessors can be accurately determined; but it is evident that we have got a weapon of wonderful power, especially in defensive positions.

Besides this, we hear of a new arm of most formidable character, which has already been introduced into the French service, "The Mitrailleur."

In a valuable paper on this subject (Journal of Royal United Service Institution, No. lvi), Major Fosbery informs us that the Montigny Mitrailleur (which may be described as a gun composed of 37 rifle barrels) will send 444 shots per minute with great accuracy up to 1,200 yards, and that without requiring to relay the gun after once ascertaining the distance. In conclusion he remarks:—

"Deliberate and continuous movements, in face of either artillery or "infantry, will become more and more impossible, and we shall have to "prepare for short and rapid concentrations from extended order, *or* "*sudden rushes from cover, natural or artificial*," &c.

Captain Majendie, R.A., thus concludes his paper on the Martini-Henry:*—

"What we have now to do is, to seek an efficient and ready means of "defence for our soldiers against these terrible arms of precision, "which can pour forth such an amazing stream of fire, consuming all "it touches. We may, by the establishment of a system of field "intrenchment, do much to afford cover and concealment to our "men," &c.

These remarks from Officers who have been specially devoting themselves to the study and development of arms of precision, are well worthy of our attention.

A few trials were made at Dartmoor of the effect of artillery fire upon hasty intrenchments, or shelter trenches thrown up by infantry, in from 18 to 24 minutes (see Figs. 9 and 10, plate XXXIV), dummies being placed behind these intrenchments, so as to represent infantry kneeling and firing. It is unfortunate for our purpose that no experiments were tried against dummies in the same position without shelter trenches. However, by counting the hits on the official diagrams that would have struck men standing or kneeling without cover, or firing from shelter trenches,† we may arrive at an approxi-

* "Journal of the Royal United Service Institution," No. lv, p. 380.

† For this purpose, I constructed diagrams (on a scale corresponding to the large photographs of a single rank of 15 men standing and kneeling, as exhibited in lecture room) of the targets, representing the front ranks in experiments Nos. 2 and 4, on tracing cloth, applied them to the photographs, and counted all hits on the figures. To obtain the probable results on the same kneeling rank if protected by a shelter trench, the ground level (or foot of the target) was taken at 15 inches (the height of the parapet) below the muzzle of the rifle, then all "throughs" were allowed to count for 6 inches from top of parapet; below that, only entire shells which would have gone through the parapet. Above the line of the crest, of course *all* hits on the figures were counted. Diagrams in Plate II show the relative number of hits standing, kneeling, and in trench, with shrapnel at 1000 yards.—G. G.

DIAGRAMS SHEWING COMPARATIVE RESULTS OF EXPERIMENT

DIAGRAM Nº I. with 15 rounds 166 hits

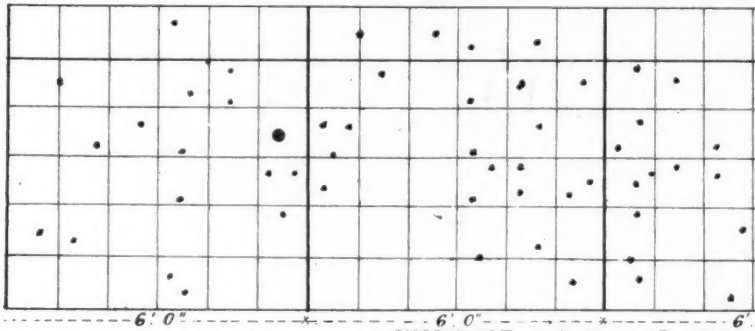


DIAGRAM Nº II with 15 rounds 107 hits

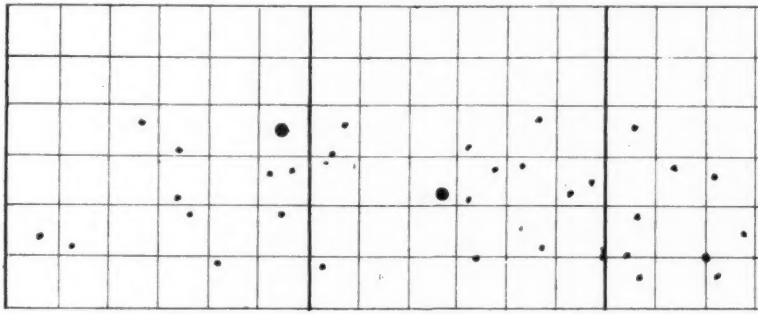
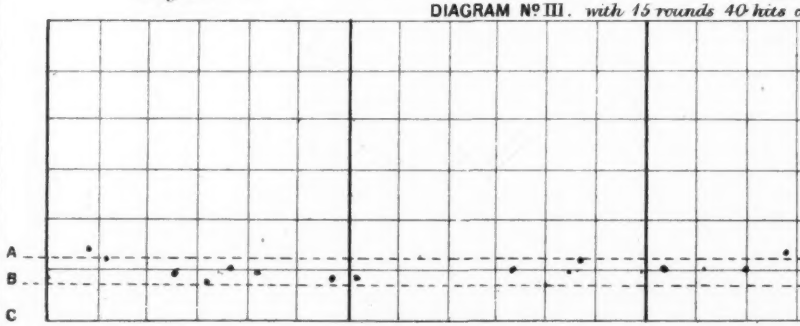


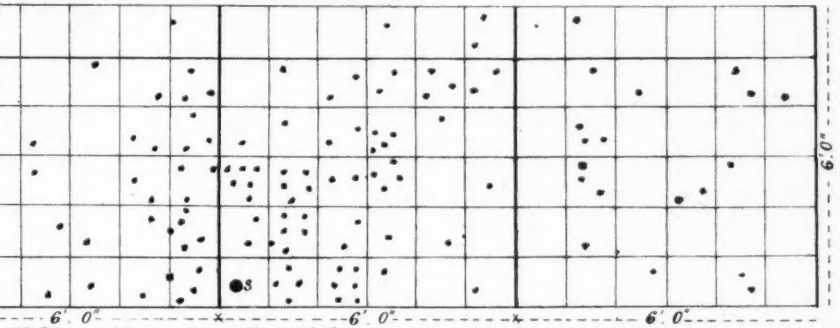
DIAGRAM Nº III. with 15 rounds 40 hits on



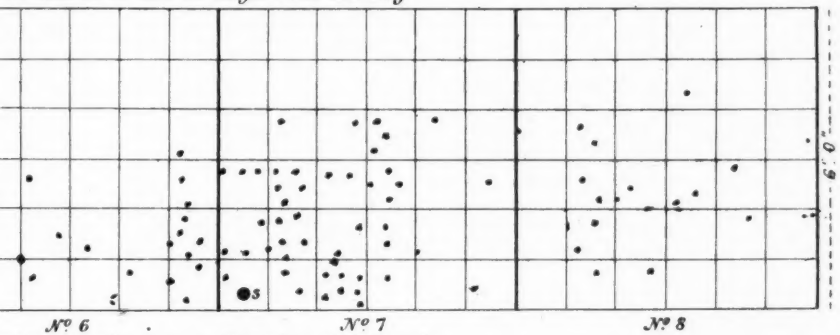
Explanation of Diagram III. The line CC 1'3" below level of muzzle
or level of bottom of Target "Throughs" only are counted between
Shell marked S. in Diagrams I.II. is not counted in Nº
These Diagrams show results on Targets 4

RIMENT Nº 4, AT DARTMOOR WITH 12 PR SHRAPNEL AT 1000 Yds

166 hits on 15 men in single rank standing

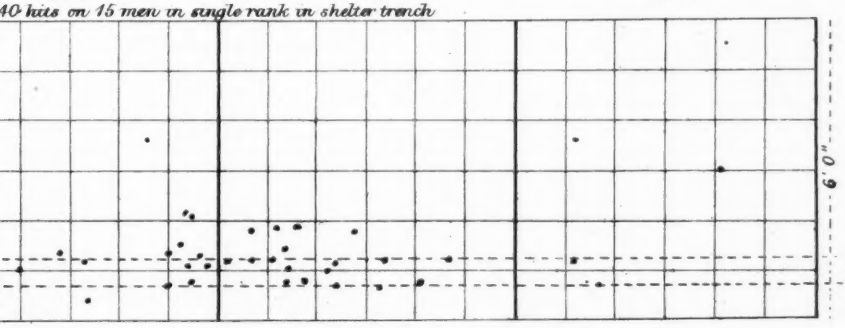


107 hits on 15 men in single rank kneeling



Nº 6 Nº 7 Nº 8

40 hits on 15 men in single rank in shelter trench



of muzzle of rifle AA (see Fig 2 Pl XXXII) is taken as ground level
d between A & B (6' below crest of parapet) & whole shells only between B & C
ds in Nº III as it passes exactly between two men
argets 4 to 8 of official diagram

J Johbins

PLANS AND SECTIONS OF SHELTER

Fig. 1.

Fig. 2.

Fig. 5.

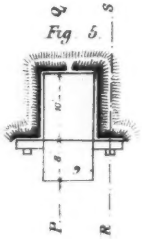


Fig. 6

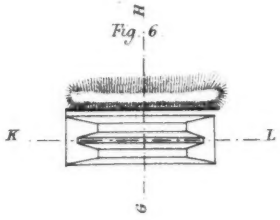


Fig. 7

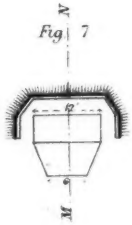
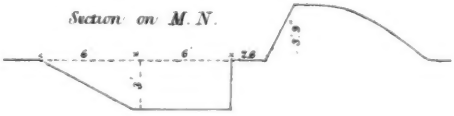


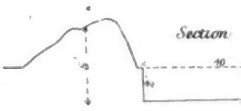
Fig. 10.

Section on M. N.



Fig

Section



Scale for Figures 1. 2.

Scale for Figure 3.

Fig. 13.

Section on R. S.

Scale for Figures 5.6 7

Scale for Figures 8 to

REFERE

Fig. 1 French section of shelter trench for 2 ranks standing area 6.52 sq.ft
Fig 2 French section " " " " " kneeling " 3.28 " "
Fig 3 Austrian section " " " 2 tusks (1 ii) area 19.69 " "
Fig 4 French shelter pit or Ambuscade-Abris Sectional area 1.64 ft

SHELTER TRENCHES, GUNPITS &c.

Fig. 3.

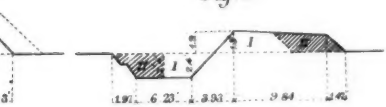


Fig. 4.

Fig. 8

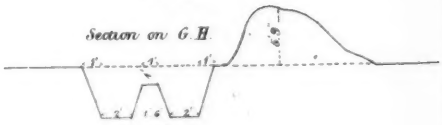
Fig. 9.

Fig. 11.

Section on P.Q

Fig. 12.

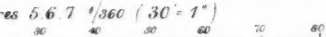
Section on G.H.



ures 1. 2. 4 1/100 (8.33' = 1")

gure 3. 1/200 (16.66' = 1")

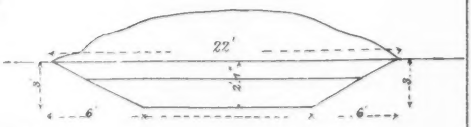
es 5. 6. 7 1/360 (30' = 1")



ures 8 to 14 1/120. (10' = 1")

Fig. 14.

Section & Elevation on K.L.



ERENCES.

DARTMOOR.

sq.r ft	Fig.5 Gunpit for 1 gun excavated by 7 Gunners in 1 hour
" "	Fig 6 Limber pit for limber & 2 horses, excavated by 5 line soldiers in 1¾ hours.
ft	Fig 7 Horse pit for 4 horses excavated by 5 line soldiers in 1½ hours.
	Fig 8 Section of Infantry trench excavated by Infantry 5 feet apart in 24 minutes.
	Fig 9 Section of " " " " " in 18 minutes.
	Fig. 10 to 14. Sections as shown by letters.

J.Jabbins.

mate estimate of the number of hits saved by the shelter trench parapet. In order to make the comparison, I have taken the hits on targets 4 to 8 only, giving a front of 30 feet, the length of the 18 minute shelter trench.

No. of Experiment.	Gun and Projectile.	Range.	No. of Hits. Standing.				No of Hits. Kneeling.				No. of Hits. In shelter trench.				Percentage saved by trench.
			T	L	S	Total.	T	L	S	Total.	T	L	S	Total.	
	12-pr. M.L.	Yards.													
4	Shrapnel..	1000	140	5	21	166	91	4	12	107	30	3	7	40	75
4	Segment..	1000	88	47	61	196	57	25	27	109	24	10	2	36	81
2	Shrapnel..	1200	28	6	8	42	17	1	5	23	5	..	1	6	86
2	Segment..	1200	11	14	25	50	2	3	4	9	1	2	1	4	92

This gives, as the average percentage of hits saved by the trench, 83½, a result very closely confirmed by comparison with the actual practice at the shelter trench on the 10th July, thus :—

Experiment No. 2, 15*th June*, 1869. *Against targets* 4 *to* 8.

			Hits.	Hits per round.	Range.
Front rank only, with front of 30 feet	8 effective rounds	Shrapnel	42	5·25	1,200 yards.
	8 ditto	Segment	50	6·25	

Experiment No. 2, 10*th July*, 1869. *Against shelter trench.*

			Hits.	Hits per round.	Range.
18 minute trench, front rank only; front of 30 feet...	2 effective rounds	Shrapnel	3	1·5	1,200 yards.
	7 ditto	Segment	3	·43	
Percentage saved by trench with Shrapnel			72		
Ditto ditto		Segment	93		
Average percentage saved by trench			82½		

We arrive, then, at this result, that for every 100 hits on a single rank of men standing upright there will only be about 18 hits on the same number of men occupying the same front if firing over the parapet of a shelter-trench. Had we the means of making a similar comparative statement of the number of hits received by a line two-deep, first standing and then intrenched (front rank kneeling and rear rank lying, as shown in Fig. 1, plate XXXV), we should of course obtain a much larger percentage of hits saved. As it is, I feel convinced that the saving shown by the above calculation very much under-states the protection afforded by shelter-trenches against artillery fire.* Thus, the supposition

* The Committee divided the hits into shots, or splinters that went through the targets ("throughs"), others that lodged ("lodges"), and others that only dinted or struck ("strikes"), and only two-thirds of the latter were allowed as hits. I have

in these diagrams, and in the trials against shelter-trenches at Dartmoor, is that the occupants of the trench would always be in the act of firing over the parapet, whereas (since no artillery Officer would, if he could help it, bring his guns within rifle range) they would more probably be lying down under cover. (See illustration, Plate XXXVI.) Besides this, the usual condition under which guns would come into action against shelter-trenches would be that of firing at an unknown range, and considering that the difficulty of seeing the trenches at all at Dartmoor from very moderate ranges was so great that flags had to be put up to show their position (although no previous attempt had been made to conceal them by branches or heather), I cannot believe that, even with Captain Nolan's telemeter, it will be an easy matter to ascertain their distance. The difficulty of striking these low earthworks was indeed shown very clearly by the experiment on July 9th, when twelve rounds of shrapnel and twelve of common shell were fired with the intention of bursting them in the parapet of the trench, "but," as stated in a report, "none could be made to strike in exactly the "proper place, notwithstanding which, the practice must be considered "as very good, as an error of one or two feet in elevation would be "sufficient to account for the distance under and over at which the "shells struck."*

Thus, then, twenty-four rounds of deliberate practice, by first class artillerymen, knowing the range, and with nothing to disturb them, *produced absolutely no effect whatever on a shelter-trench at* 1,500 *yards.*

In order to ascertain the value of shelter-trenches as a protection against musketry, it would be very desirable to have some experiments made to ascertain the relative efficiency of two bodies of infantry, one behind a shelter-trench, and the other advancing to the assault. At present all we know is that any parapet over twenty inches thick is proof against the best rifle. The following statement has been supplied to me by an Officer† who has made many experiments with the new rifle, "Supposing an attacking party 400 strong has to advance against "100 men, armed with Martini-Henry rifles, and well sheltered, 50 to "fire and 50 to provide them with ammunition, time advancing three "minutes, *by the end of the second minute there ought not to be a man left "standing.*"

As this paper will not have the advantage of being discussed at this meeting, I propose, before proceeding further, to notice the principal objections that I think can be made against the use of intrenchments in battle.

‡1. "The use of shelter-trenches is contrary to the spirit of modern

preferred counting everything as a hit. Very little suffices to disable a man, and a man disabled is for military purposes better than a man killed, as he takes off other men to attend to him. According to French experiments, a ball penetrating 16 millimetres (·63 inches) into deal will disable a man.

* Report on Dartmoor Experiments, by Lieutenants Day and Cockburn, R.E.

† Capt. Drake, R.E., Musketry Instructor. See Appendix No. 3.

‡ These first two objections are borrowed from Captain Charrin, of the Belgian Army, proposer of a musket-proof knapsack. (See "Spectateur Militaire.")

CHATHAM
SHELTER TRENCHES, &c.

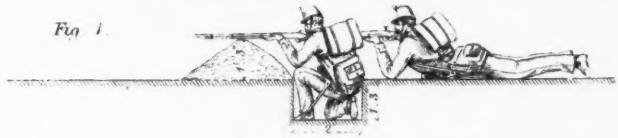


Fig 1.

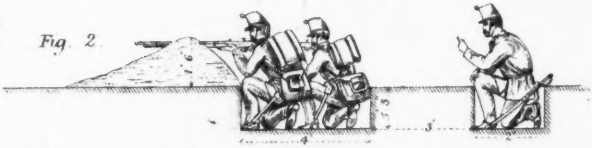
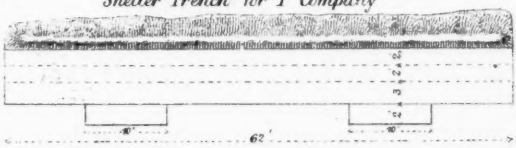


Fig 2.

Fig 3.

Fig 4 Shelter Trench for 1 Company



Charger Pits

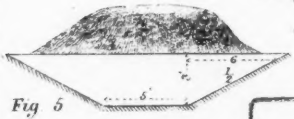


Fig 5.

Fig 6.

Fig 7.

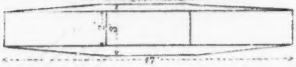
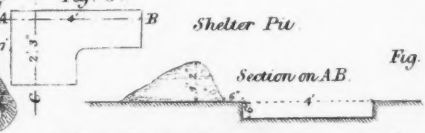


Fig 8.


Shelter Pit

Section on A B

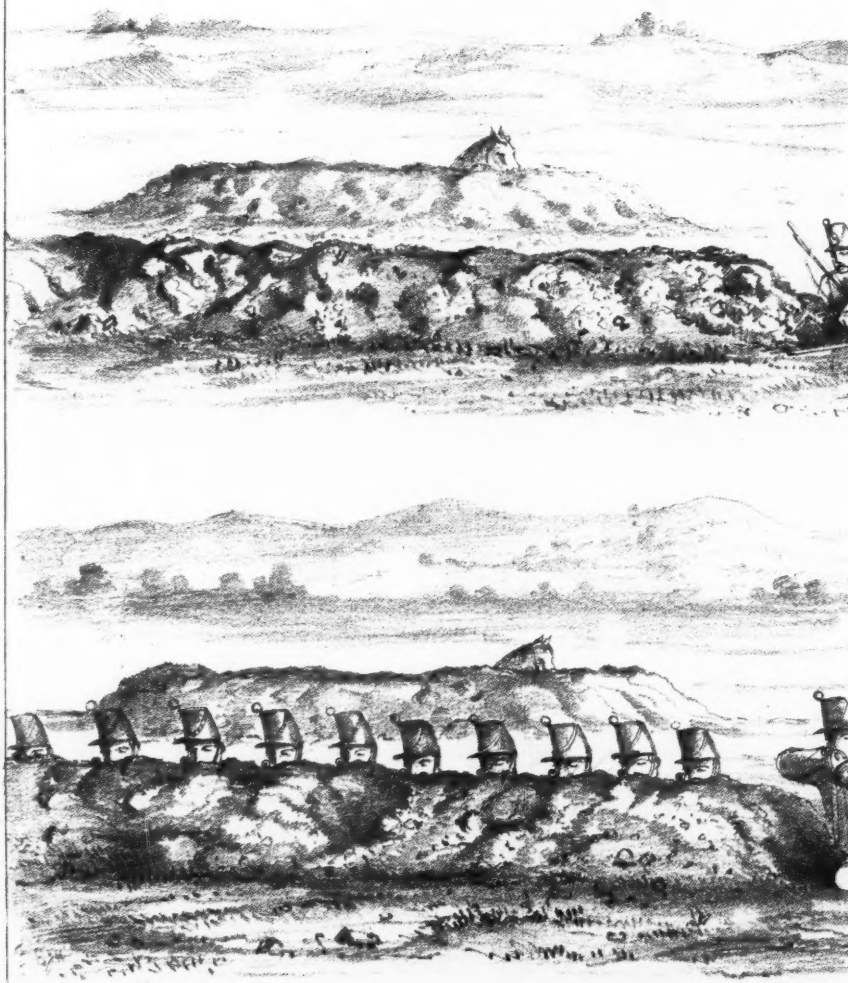
Fig 9.

Section on C D

Scale for Fig^s 1.2.3.8.9. 5 ft. to 1 inch.
" " " 5.6.7. 10 " " " "
" " " 4. 20 " " " "

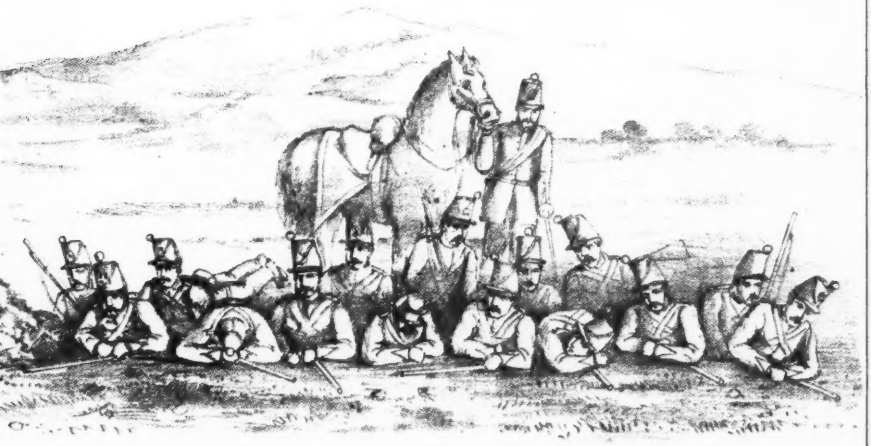
J Jobbins

BATTALION LYING
IN SHELTER TRENCH.



BATTALION IN AC
IN SHELTER TRENCH

Y ING DOWN IN LINE.
IN THE OPEN.



N ACTION IN LINE.
IN THE OPEN.

J. Jobbins.

" tactics, which requires the utmost flexibility and rapidity of move-
" ment."

Reply.—Flexibility is quite compatible with the use of shelter-trenches, which should offer no impediment to the free transit of troops; rapidity of movement is obviously not affected by them; *continuous* rapid movement certainly is incompatible with their use, but unresting rapidity is impracticable, and to attempt it would be worse than useless before rifled guns and breech-loading rifles.

2. "The ground is not always fit for intrenchments, the Army may " find itself in a marshy plain, or amid shifting desert sands, or worse " still, on bare rocks."

Reply.—This may happen, but even in such exceptional cases the troops will be all the better for having been taught to cover themselves; among rocks they will probably not need other than natural cover.

3. "Trenches demoralize the soldier, who learns to crouch behind " parapets and to fear exposure."

Reply.—On the contrary, they demoralize the soldier who has to attack them by adding to his difficulties and losses. As, however, this is a stock argument against intrenchments, I propose replying to it at greater length.

Does training a soldier and making him more able and intelligent demoralize him?

Those who hold it does, are consistent in believing, that teaching him how to protect himself, demoralizes him. It has been said by many that the trenchwork before Sebastopol demoralized the soldiers; that they lost the dash and daring of British troops and clung to parapets when they should have gone forward. As one who served in the trenches throughout that siege, I wish to give my testimony against the notion that the trenches demoralize the men. I believe that those who originated these sayings have generalized too much on individual cases, perhaps of recruits who never were soldiers, or of old soldiers who never were good ones, and that they have hastily attributed these shortcomings to the trenches. Sickness and suffering, disappointment and doubt, demoralize men, and all these our soldiers had to bear up against during that long siege. But we Engineers cannot admit that the trenches demoralized them. What troops had so much trenchwork as our Sappers, and who will say that they ever shrunk from exposing themselves when required? It is unnecessary to give instances of this, as they were doing it every day and night of the siege, when "follow the Sapper" was the order of march. I would not have noticed the Sebastopol illustration, but that I know it is often brought forward, for after all what comparison can there be between the trenches of Sebastopol, where men did duty for nearly a year, always more or less under fire, usually with very little chance of returning it, and troops lying for a short time under cover during action, either engaged, or awaiting an order to advance?

An objection has been put to me in the form of a dilemma, thus:—

4. A battle is either fought offensively or defensively; if the former then shelter-trenches are useless, if the latter, unnecessary, the best defences being detached works like those of Torres Vedras.

Reply.—This assumption is incorrect, as unless the forces are very unequal, no battle can be purely offensive or defensive. All authors agree "that defensive positions are best maintained by offensive actions" (see Sir Wm. Reid's paper), or, as the French express it, "Combat "défensif avec retour offensif." "Les armées offensives elles-mêmes "ne sont pas dispensées de se fortifier; car elles ne sont pas toujours "et en tous lieux supérieures, et elles ont à prendre quelques pré- "cautions sur leurs flancs et sur leurs derrières..... elle se dégarnira "en certains points, se contentant d'y observer son ennemi, pour agir "ailleurs avec la meilleure partie de ses forces..... elle ne doit pas "négliger..... de couvrir par des retranchements légers, ses grand "gardes et ses avant portes; la prudence veut aussi qu'elle protége "également, par quelques postes retranchés, ses derrières et sa ligne "d'opérations." (Noiset's Fortification.) The improvements in arms of precision (especially musketry) have made the defence so much stronger than the attack, that the principle so prophetically enunciated by Napoleon must now be acted on, that tactics should be based on fortification. On this principle, no Army in a defensive position will in future be attacked without previous counter-battering from guns protected by earthworks, while the troops of the first line are kept ready for the assault in a parallel of natural or artificial cover.

With reference to the character of the works of defence it will, I apprehend in future warfare, be found inadvisable to concentrate troops in detached forts without bomb-proof protection or covered communications (which hasty intrenchments cannot have). Natural cover between the forts must, therefore, be improved (commencing with mere shelter trenches) as much as possible, and the main body of troops kept in line in these intervals when most capable of taking the offensive.

At this point the question previously put may be answered, viz.: Is the use of shelter trenches compatible with our English mode of fighting?—Yes; because it is peculiarly well suited to our line formation, and therefore our troops would adapt themselves more easily to it than those of Continental nations who fight in column. To our troops, no change of formation would be needed in an advance from the line of trench, and to them there would be no change of tactics in receiving a charge in line.

To some, perhaps, it may still appear unmanly, or un-English to be under cover; but I can only allude to this feeling as a mischievous piece of sentimentalism which ought to be rooted out. Let us not in any future war sacrifice our men to any such puerile considerations as these; let us not again merit the reproach of the historian of the Peninsular campaigns: that "in the beginning of each war, England "has to seek in blood the knowledge necessary to ensure success."

We have now to consider what form of trench is best adapted for the field. Fig. 1, plate XXXIV, is the profile recommended by the French; it is large enough for two ranks and gives cover to men firing standing. Fig. 2 is for two ranks kneeling; in both, the parapet is thick enough to resist musketry.

Shelter trenches of this kind have been thrown up in the French

camps in 25 minutes in ordinary ground, and in 35 minutes in very difficult soil. In July, 1868, the Italian Army, encamped at Fojano, made shelter-trenches with untrained troops. 150 men in 25 minutes made a trench of 93 metres length in stiff clay, and later 128 men made in similar soil a trench of 100 metres in 30 minutes.

The Austrians have made many experiments in shelter-trenches. Fig. 3 shows the profile recommended by them.* Fig. 1, plate XXXV., is the Chatham section for a shelter-trench as given in the Field-book of Instruction. "Such a trench can be executed by men with their "accoutrements on, distributed at from 4 to 6 feet intervals in from "10 to 20 minutes. This is the smallest trench that is of any use and "will afford cover to two ranks, one kneeling in the trench and one "lying in rear of it." This trench can be widened, as shown in Figs. 2 and 3, or men skirmishing may make shelter pits for themselves, such as shown by Figs. 8, 9, plate XXXV. This may be made in from 2 to 4 minutes with very little practice by one man of a file of skirmishers. The same thing is practised by the French (embuscade-abris). See Fig. 4, plate XXXIV. Branches, bundles of underwood, &c., may be used for screens. Charger pits may sometimes be necessary, such as shown by Figs. 5, 6, 7, plate XXXV. This can be made by four men in half-an-hour.

Plate XXXVI is a photograph from a spirited drawing by Lieut. Conder, R.E., showing a detachment in line both in action and at rest, with or without protection. The advantage of the parapet is too evident to need further remark.†

Figs. 5 to 14, plate XXXIV., show plans and sections of the shelter trenches, gun and limber-pits used at the experiments at Dartmoor, already referred to.

Two gun-pits were made, each for one gun and its detachment—excavated by seven gunners in one hour. A roughly-constructed model of a field-gun, and six dummies to represent the detachment, were placed in each.

Experiment 1 was with 12-pounders at 930 yards. Results: with shrapnel, 2 killed, 2 wounded, gun and carriage untouched; with segment, 2 killed, 1 wounded, gun and carriage marked by splinters.

Experiment 2 was with 12-pounders, at 1,525 yards; 12 rounds were fired with each. Results: with shrapnel 2 killed, carriage injured; with segment in gun-pit *nil;* but, in limber-pit, limber much injured, horse killed. On the 9th June, 12 rounds of segment at the same range were again fired at this pit with no results.

This practice seems to have led some Artillery Officers to the conclusion that gun-pits are of little or no use; but I would submit to them, for further consideration, that the conditions under which these experiments were conducted were not precisely those of war. Thus, the exact range was known, the gun-pits were isolated works, so as to show a distinct mark to the gunners, whose aim was further assisted

* Taken from Col. Brialmont's pamphlet, "La Fortification Improvisée."

† It will be observed that this drawing is taken from a very commanding position, in full view of the parapet of the charger pit, which would otherwise be hardly visible over that of the shelter-trench.—G. G.

by small flags planted in the parapet, though it is true they had not the flash and smoke of answering guns to guide them (if, indeed, that is a guide beyond point-blank range). Then the gun-detachment being dummies were always standing at their guns instead of running in occasionally and "hugging the parapet," as sensible *live* gunners would do, between the rounds; at all events, to test the value of the protection, some similar dummy gun-detachment ought to have been placed in the open and fired at from the same range. In 1862, a trial of this kind was made by the Ordnance Select Committee at real guns and carriages. They report the result of 12-pounder segment shells at 1,000 yards as follows:—"The carriage of the gun fired at with segment shells was "severely cut up, one wheel being completely destroyed." Later in the year, they renewed the experiment at 600 yards, this time providing the gun with a dummy detachment. The results of firing with the 12-pounder gun was then as follows:—"All the detachment "were struck, several of the dummies were cut to pieces; car- "riage described as being knocked to pieces; portion of a wheel "carried 30 yards to the rear." It is therefore evident that bad as the inside of a gun-pit may be under artillery fire, it is better than the outside; besides, it must be remembered that gunpits are also intended as a protection against Infantry fire, and although unfortunately no experiments with small arms were made at Dartmoor, yet we know that a rifle bullet will not penetrate more than 12 inches of earth at 220 yards, and that the exposure of gunners firing from a gun-pit is certainly not one-quarter that of the same men unprotected. By the experiments at Hythe in 1856 with rifle practice against guns and dummies at 800 yards, it was shown conclusively that artillery would be beaten off the field by infantry, armed even with the Enfield.

A similar experiment was tried in Austria a short time since, when a company of infantry of 200 men opened volley fire on a field battery (8 guns), having dummy men and horses, with the following results:—

At 1,000	yards—	126	hits out of	1,100	shots, or	11½	per cent.	
800	„	250	„ „	1,460	„ „	18	„	
600	„	299	„ „	1,600	„ „	19	„	nearly.

Thus at 1,000 yards they would have made 115 hits per minute, at the deliberate rate of five shots per minute, or sufficient to disable the entire battery in one minute.*

The following is a brief account of the method of forming shelter-trenches as practised at Chatham in accordance with the drill instructions now preparing for issue:—

The battalion having been formed in quarter column on one flank of the tools, the rear ranks file out, each man taking a tool as he passes the markers, who distribute shovels to all the odd, and picks to all the even numbers. On the march the tools are transferred from one rank to another, to relieve the men, but on arriving near the position of the proposed shelter-trench, the tools are again taken by the rear rank,

* See also an interesting paper on this subject by Lieut. Walkey, R.A., in Proceedings of R.A. Institution, December, 1866.—G. G.

who form the trench, while the front rank open fire or lie down, or remain standing in advance, according to circumstances. The markers are then ordered out and placed along the intended line of trench, usually following the contours of the ground; the rear rank in the mean time form two deep, pile arms and prepare for work. The line of trench may then be marked with picks or tracing tapes. About three-fourths of the odd numbers of the rear rank then extend at double arm distance, touching each other with extended hands, dressing by the markers, who extend one arm. The odd and even numbers then work together in pairs, each pair occupying about 5½ feet of ground, and making the trench 2 feet wide and 1¼ feet deep, only one man working at a time. To place the men thus, takes usually about two minutes from the time of arrival on the ground to the moment of commencing work. The remaining quarter of the rear rank are employed on the trenches for the officers and supernumeraries, and on the charger pits.

The Austrian method is to place two men to every 3 Austrian feet run (about 3 feet 8 inches English), thus employing two-thirds of the number of men to be covered. This must cramp their working powers, being too confined. The French place one man per metre (about 3 feet 4 inches), and thus employ one-third the number to be covered.*

Colonel Brialmont proposes forming the battalion with double files, carrying shovels, alternating with single files carrying picks; halt them at four paces from the site of the trench, and open the ranks, laying arms and packs on the ground; the front rank then advances with tools, each group of three establishes itself in a portion (atelier) of 1·80 metres in length (corresponding to the space occupied by three men in the ranks, 5 feet 10 inches, or 23·72 inches per man). Two of these men have spades, the third a pick. This latter places himself between the two first and in rear of them. After 10 minutes' work, the men of the second rank who are lying down behind their arms, relieve those of the first rank. The intrenchments are thus executed along the whole extent of the front with the co-operation of all the men. One half of them guard the other half, and in less than a minute, in case of unforseen danger, the battalion would be under arms.†

As may be seen, therefore, the main points of difference between our method and that employed on the Continent are—1st, that we use equal numbers of picks and shovels, while they use only one pick to every two shovels; and, secondly, that they make no provision for supernumeraries, &c., who, they say, can enter the shelter-trench with the men, or sit on the reverse of it when large enough.

With reference to the 1st point, we find it best to provide equal numbers of picks and shovels, our men always working by files or pairs, and in the shelter-trench, as only one works at a time, he has both pick and shovel at his command. As regards No. 2, it is considered better for purposes of supervision and discipline, to have distinct positions for the officers, &c.

* Six workmen, four shovels and two picks, to 5·20 metres length (=17 ft. nearly) = a space of nine files, or 18 men, each file in the ranks occupying about 58 centimetres (22·83 inches).—G. G.

† "La Fortification Improvisée."

It would be beyond the imposed limits of this paper to enter into any description of the application of shelter-trenches to the field of battle. Here the engineer and tactician should combine, the line of front should be in extent exactly proportioned to the number of troops; in fact, "the defences should fit like a garment on the body "of the Army,"* loose and free where action is required, close and thick where protection is wanted, in other words, the field should be divided into offensive and defensive portions. In fact, fortification, here on the battle-field as elsewhere, should be employed to economise men, and in this it may be compared to those mechanical inventions which are used to economise manual labour, and especially to such as store up the accumulated results of labour. Thus the fortified posts of a line of battle may be likened to the fly-wheels of a shaft, they are "magazines of power," so that the force expended on them at the beginning will be recovered again at the end.

The preparation of a field of battle, as thus indicated, pre-supposes choice of ground and time for execution. For instance, supposing the army came into bivouac on the position chosen the afternoon of the day preceding the expected action; they rest, if tired by the march, while the General and his Staff reconnoitre and decide on the works to be thrown up. Then, in half a hour before dark, the shelter trenches could be completed, while the more important works of the defence could be executed by skilled troops during the night.† It will be a great advantage in these hasty intrenchments over more solid works, which take longer in execution, that the enemy will necessarily be in ignorance of their exact strength and position. On the other hand, the General of an army acting on the offensive, will make use of shelter-trenches according to his intended tactics and what he expects from his enemy. Thus he may have to intrench an exposed flank, or a part of his line denuded of troops, which are massed for attack in another part. His first line should always be under cover, natural or artificial. Large openings, or intervals between the trenches should be left, sufficient for grand divisions of infantry or squadrons of cavalry on the flanks of brigades, besides the battalion intervals, which might be half those of the brigades. The lines of shelter-trench should be straight or following the contours of the ground—not broken into flanks. In that remarkable paper written 30 years ago, on "Intrench-"ments as Supports in Battle,"‡ from which I have already made extracts, an account is given how the slight works at Fuentes d'Onoro, thrown up in presence of the enemy, foiled the French attack. Massena explained his failure by representing "the enemy, drawing to their "assistance all the resources of fortification against an attack by main

* "Passend wie ein Kleid am Körper der Armee."

† On the defensive parts of the field the shelter-trenches should, if time permit, have the excavation on the front side, so as to offer a greater obstacle to the enemy. See paper by Sir J. Burgoyne on Hasty Intrenchments, vol. xviii., P. P. R. E.—G. G.

‡ By Colonel Reid, R.E., the gifted author of the "Law of Storms," &c. See Sir F. B. Head's humourous, but highly appreciative notice of Sir William Reid, in "Royal Engineer," pp. 298, 299.

"force."—(*Times* newspaper, 29th May, 1811.) "But," says Sir William Reid, "however much every man in that army, at that "moment, might have been desirous of availing himself of all the "resources of fortification, such was not within his reach; for it is "supposed that this portion of the Army had no other intrenching "tools than the few carried by the regiments for the purpose;* and "there was but one engineer officer present."

The question of tools will have to be considered in connection with this subject; the scarcity and want of them was probably the principal reason why field fortification played such a secondary part in our Peninsular campaign, as the practical sagacity of the great Duke seems to have impressed him with an ever-growing conviction of its importance, of which many instances could be given from his late campaigns.†

Sir W. Reid relates that after the battle of Toulouse, the British Army was to have been intrenched. "Strong country houses were "fortified at about every 600 or 800 yards from each other, etc. . . "in rear of the intervals straight trenches were just about to have "been commenced when the enemy's army retired." Again at the operations of the passage of the Nive, intrenchments were used. It is indeed pretty certain that the Duke of Wellington contemplated intrenching the field of Waterloo, as is shown by a memorandum of his (dated 22nd September, 1814), on the defence of the Netherlands, quoted by Sir Francis Head ("The Royal Engineer," p. 326), and the same authority states that an order was given on the eve of the battle (too late for accomplishment) to a company of Royal Engineers to march to Braine-la-leud, and there make an intrenchment for the right of the position of Waterloo.

We learn also from Napoleon's Memoirs, that he expected to find the Allies intrenched at Waterloo, and especially charged General Haxo to reconnoitre and ascertain this point. Yet at the battle of Waterloo (as elsewhere, under the Duke of Wellington), although the troops were not intrenched, the principles here advocated of keeping troops under cover until the time arrives for advancing, were carried out as far as was possible with natural cover only.

Quoting again from Sir W. Reid:—"It was the custom during "the late war for the British Infantry, when they occupied a de-"fensive position, to draw up just behind, and under cover of the "slope of a ridge, when there was one, from whence the lines were "brought forward to charge at the proper moment." They were also taught to take advantage of any natural or artificial cover they could find, thus at the battle of Waterloo, the first check to the French attack on Wellington's left centre was from three companies of the

* One mule per regiment for intrenching tools. G. O. Abrantes, 19th June, 1809.—G. G.

† There is difficulty in citing instances, as the cases where intrenchments were used in the battles of the Peninsula appear to have been imperfectly recorded and preserved. Sketches by Sir Phillip Bainbrigge (who was Assistant Quartermaster-General in the Peninsular war) exist, showing that not merely parapets and ditches, *but long lines of cover*, following the contours of the ground, were constructed by the Duke in Spain.—G. G.

95th Rifles, who were posted in a sandpit and along a hedge in rear of it. Kempt's Brigade lined the hedge of the Wavre road, fired a volley on the French central column (which was in the act of deploying), and then made a charge, but was delayed and somewhat disordered by the difficulty of getting through the hedge. The 79th Highlanders, in particular, suffered greatly, and here it was that Picton was killed.* This shows clearly the necessity that the cover obtained should be of a nature not to obstruct the advance of the troops. Hence the hedges and ditches of cultivated districts are rarely suitable for offensive defence without special preparation; and although natural cover, such as that afforded by gentle slopes and undulations, will continue to be extremely valuable, it will be found in most cases insufficient to protect troops from the explosive projectiles of modern rifled cannon, as was clearly shown by the experiments at Dartmoor (already referred to), against columns partly concealed by rising ground.

Now, at the battle of Waterloo, we know that about 1.30 p.m., Napoleon advanced 10 batteries (74 guns) to within a range of 600 to 800 yards from the English line to support the attack on Picton's division, already referred to. Siborne says, "The nature of the ground "permitted the batteries to play over the heads of the three advancing "columns of French infantry, and great was the havoc in Picton's ranks."—(Siborne's Waterloo.) Supposing the battle had been fought with the arms and experience of the present day, it is certain that Napoleon would not have advanced his guns within 800 yards, as they could make havoc and destruction enough at double that distance. It is indeed awful to consider what would be the effect of 74 guns acting on unprotected columns† of troops, when we consider the practice at Dartmoor. By experiments 13 and 31, as already stated, a column of targets may be hit over 1,000 times with 15 rounds. Allowing now that one-half of these were caused by "throughs," still 2 rounds per minute from 74 guns would inflict nearly 5,000 hits per minute; sufficient, one would think, to have cleared Picton's division off the face of the earth in ten minutes. But, it may be said, *our* guns wouldn't have been idle all this time, the French would have suffered at least as much as we should. True, on the fair fighting principle of equal exposure, but supposing the French had intrenched themselves, as they did at Chalons, the other day—supposing that Napoleon had devoted one hour, or even one half-hour of the three he spent in parade, to making "tranchées-abris." Who here would wish to see the fate of Europe, the honour of England, risked in such an unequal conflict, and what General would expose his troops to be thus helplessly slaughtered?

Then look at Alma. Our advance—nearly 2,000 yards—over ground swept everywhere by the fire of the enemy's guns, at marked ranges; the storming of the great redoubt, up 200 yards of a glacis slope, in the teeth of guns and musketry; the advance of the Guards "in an

* "Siborne's Waterloo." There appears also to have been an abatis across the Charleroi Road, near the sandpit.—G. G.

† Picton's division at this time was in battalion columns at deploying intervals, as we read that he did not deploy his troops until after the retreat of the Dutch-Belgians (Bylandt's brigade).—G. G.

"array which was all but found fault with for being too grand and too "majestic."* Would this be possible against guns such as those used at Dartmoor, and rifles such as the Martini-Henry, in the hands of an enemy practised in the art of getting cover? Of what avail would be the splendour of our line—the majestic grandeur of our advance—against an intrenched body of troops, who would show only the peaks of their caps and the muzzles of their rifles, each rifle being kept steadily resting on the bank before them, and volleying destruction at the rate of 10 to 15 rounds† a minute? Even, with the arms he had, supposing Menschikoff had intrenched himself, could we have stormed the Alma heights as we did, or, indeed, should we have attempted it?

What prevented our assaulting Sebastopol as soon as we arrived before it? Not the ditches, or escarps of the fortifications (which indeed were at that time mere hasty intrenchments growing under our eyes), but our knowledge that works, the approaches to which are well commanded by artillery, cannot be taken except with terrible sacrifice of life, and we knew that, situated as we then were, repulse meant ruin.

I cannot see how, then, we can avoid the conclusion that in future wars, our soldiers will have to protect themselves in the same way as the soldiers of other armies, and that for this we must prepare in times of peace, or we may find it too late when war arrives, and vainly oppose human daring and self-devotion to the inexorable laws of the science of destruction.

Granting, then, that our troops must shelter themselves, it remains for us to consider the means. The question of the transport of tools is one that is surrounded by great difficulties; the root of it is this: Shall the soldier in future carry his tools himself, or get them carried for him? There is strong authority for the former method. Colonel Brialmont states that in Russia, the system of giving every man a tool to carry is on trial; that in Denmark, a tool has been given to each file; in Prussia, to the soldiers of the Jäger battalions only; and that, in the American army, the tools of each battalion are carried according to roster by the men of two companies.‡ (Appendix IV.) Colonel Brialmont himself is in favour of the soldiers carrying their own tools, as their doing so would diminish the "*impedimenta*"—the transport—of the Army, and accelerate the execution of the work. The Drill Committee, in reporting on the instruction of regiments in intrenching themselves, have arrived at the same conclusion, considering that by any other system of transport, the tools would not be at hand when required. There can be no doubt but that there are very strong reasons in favour of adopting this system, and it has the approval of very high authority. Napoleon himself wished every soldier to have a pioneer's tool,§ and indeed made an attempt to get every sapper to carry one, offering "to make it more palatable," that "it should be of

* Kinglake's "Crimea." Quoting observation of a French Officer.

† Of course this rate of fire could not be kept up, but a fraction of a minute might be sufficient.—G. G.

‡ "La Fortification Improvisée," p. 39.

§ "Memoirs at St. Helena," Montholon i, pp. 248, 249.

"superior manufacture, and an implement *de luxe*, as it were; but "after much discussion on the objections raised to putting this addi- "tional weight on a class of men who frequently had to set to work "immediately after a march (*and this will now often be required from* "*all classes of the troops*), he was obliged to abandon the idea."—("Hasty Intrenchments in the Field," by Sir J. T. Burgoyne.)

This difficulty of weight, before which the great military autocrat had to bow and submit, now stands before us, and demands our careful consideration. Many consider that in these days, quick manœuvring and necessity for rapid motion when advancing under fire, will make it obligatory to reduce the weight carried by the soldier below what it has ever been before; and it is a very common opinion, since the short campaigns of Italy and Bohemia, that it will be unnecessary to load him with so much personal kit. The recommendations of General Eyre's Committee embodied these opinions, and I have collected all the information I could find on the comparative weights of different kits (see Appendix V), which I will not now trouble you with. It is sufficient to state, that it is quite feasible to give the soldier an intrenching tool, to increase his present allowance of ammunition from 60 to 100 rounds, and yet to give him less to carry than he has at present, thus:—

Articles to be carried.	Weights (approximate).		Remarks.
	As at present.	As proposed.	
	lbs.	lbs.	
Arms and ammunition	16	20	Including 100 rounds of ammunition, the same as the present French war allowance.
Accoutrements and pack ..	10	4	
Clothes on person	11	10	
Kit, with blanket	14½	11½	For details of Kit, see Appendix No. V.
Food and water	8	8	
Intrenching-tool	..	3	
Total	59½	56½	

But, in attempting to solve this question, the feelings of the soldier himself must be taken into account, and it will not do to answer it merely by making out an arithmetical statement of weights, and supposing it to be a matter of indifference to him what he carries, and that he only concerns himself with its weight. At present, I feel convinced, though I say it with regret, that the British soldier would consider it a great burden and grievance were he to have to carry an intrenching tool in addition to his kit; that he would feel that extra 3 lbs. more than all the rest, and that telling him that the rest of his kit had been lightened on purpose would be of no use. This feeling, or prejudice, is no doubt remediable, and I feel sure that the time will

come when the British soldier will value his spade as second only to his rifle, never to be put aside in the field.

Assuming, then, for the present, that the soldier does not carry his intrenching tool, there remain the three systems of transport to select from, the Army Service, the Regimental, and the Royal Engineer Train. By the first two methods, it is very doubtful whether the tools would ever be at hand when required, as they would be mixed up with all sorts of other stores, and in the not unlikely contingency of deficiency in transport, the tools would probably be left behind in deference, perhaps, to urgent demands for such stores as provisions, ammunition, clothing, &c. The Engineer Train, on the other hand, would feel it a point of honour to have the tools well up to the front; to them their tool-carts would be what their guns are to the artillery; they also would know tools required repair, and draw on the reserves accordingly. It would, however, be necessary to take precautions for obviating the objection made to this system of transport by General Faidherbe,* that "supposing a battalion expects to be attacked, and "wants to get cover, it is necessary to get the General of Division to "give an order to the Engineers of this division to supply tools."—("La Fortification Improvisée.")

I would propose that each brigade should have a detachment of the Royal Engineer Train, who would carry the light shelter-trench tools for the infantry (one to every three men of the brigade), in addition to the ordinary engineer field equipment. The shelter-trench tools for one brigade would all pack in a wagon (see Appendix VI), and should be entirely at the disposal of the Officer commanding the brigade, or, indeed (if thought desirable), they may be issued to Commanding Officers of regiments. When approaching the enemy, these tools should be issued as required, each being provided with a light strap, so as to be carried without interfering with the use of a man's arms. I do not fear that, in presence of the enemy, and with full proof of its value, the soldier would object to carrying an intrenching tool. In the advanced trenches before Sebastopol, when night sorties were expected, I often found the men of the working parties would not part with their rifles, but carry them on one shoulder, and their filled sandbags on the other, sometimes, owing to scarcity of earth, a considerable distance.†

This same feeling which led these hard-worked men thus voluntarily to submit to extra labour, in order to be effective if attacked, would soon teach their successors to keep their spades as well as their rifles.‡

* "Revue Militaire Française," August, 1869.

† Thus, too, worked the Jews of old at the repairs to the walls of Jerusalem, under their inspired prophet-leader. "For the builders every one had his sword "girded by his side, and so builded" (Nehemiah, iv, 18). As a precedent for our shelter-trench drill, we might refer to verse 16 of this chapter, where we read, "And "it came to pass, from that time forth, that the half of my servants wrought in the "work, and the other half of them held both the spears, the shields, and the bows, "and the habergeons."

‡ A mere caprice will sometimes induce a soldier to load himself heavily for a

Whatever system of transport we adopt, it is certain that it must be one which will ensure the tools being always at hand when required. Here, again, Waterloo supplies us with an illustration. As Englishmen, we do not, of course, like to admit that at any period of that great battle we appeared likely to lose it. Yet many writers, and among them General Sir J. Shaw Kennedy (who was present as General Alten's Assistant Quartermaster-General), consider that, when La Haie Sainte was taken, the allied Army was in great peril. "The possession of La "Haie Sainte by the French," he writes, "was a very dangerous incident. "It uncovered the very centre of the Anglo-Allied Army, and established "the enemy within 60 yards of that centre. . . . The danger was immi- "nent, &c. . . . Most fortunately, Napoleon did not support the ad- "vantage his troops had gained at this point, by bringing forward his "reserves. This peril was undoubtedly, in a great measure, the fruit "of the vast importance of holding La Haie Sainte, not having been "seen, *and the consequent neglect of its defences.*"* Colonel Chesney corroborates this statement of the critical state of the British Army at this period, and quotes the concurrent testimony of a number of foreign writers. The common reason assigned for the loss of this important post, is the want of ammunition; but, as General Kennedy says, "this is unexplained;" and Siborne supplies another, which may help us to understand why the brave German garrison failed at last after repeatedly repulsing the desperate assaults of the French. "*The "mule laden with regimental trenching tools had been lost the day "before, so that not even a hatchet was forthcoming.*"—(Siborne's "Waterloo," vol. i, p. 337.) This was a grievous misfortune, especially as, with the recklessness of soldiers, the garrison had weakened their defences on taking possession of the farm on the evening of the 17th, by breaking up the great barn door on the west side for firewood on that wet, cheerless night, so that, in fact, they made a breach in their citadel for the enemy to enter by, and in the absence of their tools—with "not even a hatchet"—they seem to have been unable to stop it up, for we read that the French constantly attacked at this open end of the barn, and ultimately made their way in through it.

Now, if the course of history could be reversed—if the early display of the Prussian force had not drawn off 16,000 troops from Napoleon's reserves, and he had pushed the advantage gained by him through the capture of La Haie Sainte, might not the historian of that campaign have pointed warningly to that stray mule of the 2nd battalion King's German Legion as having carried the fate of Europe on his back? Would that loss have happened had these tools been in charge of the Royal Engineer Train? I answer No, confidently; and ask in return, do we ever hear of stray guns of the Royal Artillery being missed in this way?

One branch—perhaps I ought rather to call it the root—of this subject remains for our consideration; but I have only time to allude very

march; thus Sir J. Burgoyne relates how, in the Peninsula, one man, a shoemaker, carried a lapstone—another soldier a pet dog—in his pack.—G. G.

* "Notes on the Battle of Waterloo," by the late General Sir Jas. Shaw Kennedy, K.C.B., &c., &c., pp. 123, 124, 127, 129.

briefly to it. Our Army, to be prepared for war, requires, above all things, instruction and practice in field engineering; and with a School of Military Engineering at Chatham, it appears strange that measures are not taken for passing regiments successively through a course of field works. The Drill Committee, in reporting on the instruction of regiments, &c., have, however, recommended this measure, and also that regiments should send Officers and Non-Commissioned Officers to the Royal Engineer establishment to form classes, as at Hythe, so that we may hope to see this soon carried out,* and also that at all stations where there is ground available, the troops may be exercised in forming these trenches. It is the wish of many (and I believe it would act most beneficially on the *morale* and *physique* of the Army) to have a *corps d'élite* of pioneers in every regiment. Men of good character, and for the most part knowing some trade—facility for learning trades being afforded to all—these men to be trained at Chatham, and employed under a Regimental Officer of Works, to be available in time of peace for repairs to barracks, and in the field, for engineering duties in connection with their regiments. But the most skilled workmen will be often little better than useless unless their own officers can direct them. Each officer should, therefore, be trained to choose positions, and to lay out intrenchments, availing himself of all natural advantages of the ground. The want of this instruction was often severely felt in the American war. Thus, we read in the reports from the Army of the Potomac:—

"Often the greatest difficulty has been in getting an Army to take "up a proper and exact line of defence at first, each regiment, com- "pany, and man digging when they find their spades, without refer- "ence to the fitness of things, indicating the necessity of more "Engineer officers."

It is, however, in no self-seeking spirit that this is put forward, and I do not think the duties here referred to are such as need Engineer officers *exclusively* for their performance. Well instructed Line officers should be quite capable of performing them, though Engineer officers should be at hand to give advice and assistance as required. Study and practice is all that is wanted to make our Line officers equal to any such emergency, and they must bear in mind what Frederick the Great was in the habit of saying to his officers, "If you wish to learn the art of war, study fortification."

The CHAIRMAN.—Gentlemen, I am sure that you will all join with me in thanking Colonel Graham for the interesting address he has so kindly given us, on this most important subject—a subject that increases in importance with every fresh development of the destructive powers of guns and small arms. More than thirty years ago, Sir William Reid, to whom reference has been made by Colonel Graham, wrote, that "no army can be complete in its code of field exercise, "unless that code includes rules and exercises for intrenchments in "battle;" and again, that "the infantry soldier should be taught,

* Were our existing regulations on this subject merely carried out in every regiment as directed, paragraphs 371, 372, "Queen's Regulations," a step would be gained.—G. G.

"while he is yet a recruit, that the construction of intrenchments is "a part, and a very important part, of his duty." This, I trust, will now be the case in the British Army, as a "Shelter Trench Exercise" has been introduced into the proposed new field exercise, which will next week be submitted to H.R.H. the Duke of Cambridge. And I venture, moreover, to hope that the School of Military Engineering at Chatham will turn out as many skilled instructors and workmen, as the School of Musketry at Hythe does of rifle instructors and first class shots.

Appendix No. I.

Portable Defences.

Several different propositions have been made for utilizing the knapsacks as cover for troops when advancing under fire. Captain Charrin, of the Belgian service, and Captain Bennet, of the 7th Fusiliers, propose making the knapsacks musket proof by plates of steel or aluminium.

Major Frank Bolton proposes that each man should carry a steel spade with a movable handle, outside the great coat, the spade answering the purpose of the metal plates in the first proposition; it has also the advantage of adjusting itself to the new valise equipment, whereas the first mentioned would require us to retain the old form of pack.

Under the supposition of troops firing from behind cover, and others making a rapid charge, these heavy plate-laden knapsacks would be a serious encumbrance, besides troops firing behind them could never improve their defences, as occasion might require. Major Bolton's plan is not open to the same objection, provided the men are to be taught to use their spades, and not merely lie down behind them, indeed the best pattern of steel spades (the American) has an area of only five square inches, barely enough to cover a man's head. Major Bolton makes no mention of pickaxes, which, however, would be necessary if the spades are to be used. One great objection to the use of the pack as a defence is that once laid down for that purpose, it would generally in the course of an action be lost sight of, and only recovered with great difficulty, if at all. As Napoleon said, the soldier should never part with his pack.

Captain Harcourt, of the 102nd Fusiliers, has another suggestion to make for obtaining cover. He proposes "that a sandbag and trowel "form part of the equipment of every infantry soldier," the sandbag and trowel to fit in a case weighing altogether 1 lb. 3 ozs.

Captain Harcourt states that with this implement, a sandbag can be filled in from two to five minutes, and that a man lying down behind the filled bag is concealed from view at 100 to 150 yards. Having had this trowel and bags forwarded to me by Captain Harcourt, I made an experiment at Chatham with the following results:—

1. With the new London trowel, a sapper (a very good workman) filled the first sandbag in 3½ minutes, the second in 4 minutes, lying covered behind *two* sandbags, in 8 minutes.

2. From the time of standing at attention with Captain Harcourt's pouch on (containing sandbag and trowel) to the time of lying down behind *one* sandbag, 4 minutes. In this case, however, he was certainly not concealed nor sheltered, although zealously striving to be, and reminding spectators somewhat of the popular story of the ostrich.

3. A shelter pit, such as that shown in Figs. 8, 9, 10, plate XXXV, was then thrown up by the same man in the same soil, with ordinary intrenching tools in 4 minutes, giving complete cover.

4. The same sapper then set to work to make a similar pit in the same soil with Captain Harcourt's trowel, and worked hard for 11 minutes without quite completing it. The soil was gravel and stones, underlying a top crust of about five inches turf and vegetable mould. As the trowel had not to go below the mould except in No. 4 trial, the soil was favourable for it.

Appendix No. II.

Comparative powers of Smooth-bore and Rifled Artillery.

The chance of hitting a target 1 metre square, at a distance of 600 metres, with the smooth-bore with 8 lbs. charge, is 4 per cent.; with the rifled Belgian gun of 12, and with a charge of 1,450 grammes 80 per cent. Probabilities of hitting a target 3 metres broad by 4 high with the French 12-pounder howitzer at 1,200 metres is 4 per cent.; with the 6-pounder rifled gun at same distance, 90 per cent.—(Taken from "Etudes sur la Défence des Etats," by Col. Brialmont.)

Captain Noble calculates, according to results obtained with a 9-pounder smooth-bore and a 9-pounder Armstrong gun, at ranges varying between 900 and 1,100 yards, that the probable error in the range of the rifled gun is..... 7·4 yards.

Do.	do. smooth-bore.....	47·2 „
Do.	in the deviation of the rifled gun.....	9·8 inches.
Do.	do. smooth-bore.....	8·8 feet.

("On the Theory of Probabilities in Artillery Practice," by Captain Noble.)

The following rectangles for smooth-bore 9-pounder, 9-inch rifled muzzle-loading 9-pounder were obtained from experiments at Shoeburyness:—

Gun.	Elevation.	Range.	Rectangle of fire in yards.	Remarks.
9-pr. S.B. ..	2°	985 yards.	147·2 × 9·1	
9-pr. Rifled M.L.	2°	1,083 „	40·7 × 1·1	Charge 1 lb. 5 ozs.

Trial at Shoeburyness by O.S. Committee, June 13, 1867, on three Rows of Targets, 45′ × 6′ × 2″, 15 yards apart.

Gun and projectile.	Charge.	No. of effective rounds.	Mean range—yards.	Total hits.	No. of hits per effective round.	Remarks.
12-pr. B.L. rifled Segment-shell....	Charge 1·5 lbs. Burster 550 grs.	9	1,244	540	60	Recorded in Appendix D, of Report on Shrapnel *v.* Segment Committee.
9-pr. S.B. ..... Shrapnel	Charge 2·5 lbs. Burster 492 grs.	23	1,235	221	9·6	

Experiments were also tried with the 12-pounder shrapnel, which are not admissible in a comparative statement, as at that time the proper length of fuzes had not been accurately determined.

Appendix No. III.

Martini-Henry Rifle.

Captain Drake, R.E., Musketry Instructor at Gravesend, has kindly furnished me with the following interesting summary respecting the powers of the new weapon:—

"1. The penetration at 700 is about equal to that of the Enfield at "350 yards.

"2. Its accuracy at 1,000 = Enfield at 600 yards.

"3. Its rapidity = Snider × 2 = Enfield × 5.

"That is Snider = $\frac{5 \text{ Enfield}}{2}$.

"In two minutes five men with Martini-Henry rifles will produce "twice the effect of ten men with Sniders, owing to superiority both of "accuracy and rapidity, and ease of loading."

In the case of an assault on troops posted behind a shelter-trench, and armed with the Martini-Henry, supposing "distance to advance "600 yards, attacking party 400 strong, defenders (Martini-Henry) "well sheltered 100 strong, 50 to fire and 50 to provide them with "ammunition, time advancing three minutes, by the end of the second "minute there ought not to be a man left standing. With the Enfield "80 men ought to be hit in the same time; with the Snider, 160."—M. D.

Lieut. Stephens, R.E., Assistant Musketry Instructor at Gravesend, has also been kind enough to give me the subjoined information respecting volley firing with the Martini-Henry:—"It was found in firing "100 rounds per man by volleys at 800 yards with a section of five "men armed with the Martini-Henry rifle at an ordinary volley target "6 ft. by 12 ft., in rough winter weather, that a percentage of 50 hits "was made.

"On one occasion, four men firing by volleys at 600 yards with the "same arm, made a percentage of 85 when firing 50 rounds.

"It was found that at both these ranges 10 rounds by volleys could "be easily fired in less than a minute and a half; indeed that was the "actual time taken for any 10 rounds of the above practices when no "hurry was made.

"Fifty per cent. of hits would be good for volley firing with the Snider "Enfield rifle at 400 yards, and 10 rounds by volleys with this arm "could not be fired with effect in less than two minutes and a half.

"The last-named rifle would be of no use for firing in the ranks at "long distances.

"Independent firing with the Martini-Henry rifle at long distances, "although good, was not so effective as volley firing, and on service "would cause great waste of ammunition.

"On one occasion, five men firing independently at a volley target at "300 yards with the sights up for two minutes (the time usually taken "to fire 10 rounds with the Snider), placed 112 hits on the target, "having fired between them 121 rounds, out of which two cartridges "missed fire.

"Men leaning against the parapet of a shelter-trench, besides being "protected from the shots which might actually strike the parapet itself, "would be a most difficult mark to aim at, and consequently most of "the shots fired at them would go over or fall short of them, while they "on their part, with the parapet for a rest, would be in a most excellent "position for firing with accuracy."

Appendix No. IV.

Experiments with Tools.

An ingenious shovel, the invention of Capt. Linneman, of the Danish Army, was tried at Chatham.

Weight of shovel	1 lb. 12 ozs.	On one side of the blade is a saw, the other an axe; the whole blade will make a frying-pan.
Ditto of scabbard and belt	0 „ 10½ „	
Total weight	2 lbs. 6½ ozs.	

In very easy soil, such as sand, they were found to do very well, but they are useless in difficult soil, as they hurt the men's hands; the saw-edge gets destroyed after very little work, and the axe-edge gets blunted.

Experiments were also tried with a pickaxe and shovel proposed by Col. Bray, and two patterns of American shovels. The portion dug out by each was 4′ × 2′ × 1′ 3″ deep, in rather difficult soil, though soft from wet.

Tools.	Weight.	Cubic feet dug.	Time taken to complete.	Remarks.
Service pick ..... And shovel.....	7 lbs. 9 ozs. 5 „ 2 „	10	11 minutes	
Colonel Bragg's.... Pick and shovel....	P. 5 lbs. 6 ozs. S. 4 „ 11½ „	10	14½ minutes	Rather clumsy, considering its weight; thumb-screw and blade-work loose.
Chatham pick..... American shovel, No. 1	2 lbs. 8½ozs. 2 „ 4¾ „	10	11 minutes	Soil rather easier than the others, pickaxe broken before completion, which caused some delay. Best sapper working.
Chatham pick..... American shovel, No. 2	2 lbs. 10½ozs. 2 „ 3 „	10	16 minutes	The rounding of the corners prevents the foot being used with this shovel.

A crutch is much wanted on the ends of the handles of the American shovels. The steel blades clean themselves much better than the blade of an ordinary shovel. The shovel without the shoulders rounded off (No. 1) can be used very well as a spade, the blade being stiff and strong, and there being plenty of room for the foot. The blade might with advantage be made a little longer, and the handle perhaps a little lighter towards the ends, so that with crutch the whole weight may not exceed 2 lbs. 8 ozs. It was considered that this would make an admirable tool for infantry to carry for shelter-trenches.

Appendix No. V.

Weights carried in the Field.

British.

Articles.	Approximate weights.		Remarks.
	As at present.	As proposed.	
	lbs. oz.	lbs. oz.	
Rifle and bayonet	10 0	10 0	* Made up to 100 rounds, the present French war allowance.
Ammunition	6 0	10 0*	† As proposed by Gen. Eyre's Committee.
Canteen	1 8	1 8	‡ Made up as follows :—
Pack and accoutrements ...	10 2	4 3†	
Field kit	8 0	5 0‡	
Clothes on person	11 0	10 0§	
Water bottle and water ...	2 0	2 0	
Three days' provision	6 0	6 0	
Blanket	5 0	5 0	
Intrenching tool	....	3 0	
Total	59 10	56 11	§ Deducting chaco.

‡	lbs.	oz.
1 pair of socks	0	4½
1 towel	0	7½
1 comb	0	0½
1 piece soap	0	4
1 spoon	0	2
1 shoebrush	0	4½
1 clasp-knife	0	1½
Thread, needles, &c.	0	0½
1 flannel shirt	1	1
1 pair of shoes	2	0
Total	4	9½

French.

Weight of arms and equipment, 1857....	72 lbs.	As given by Dr. Parkes, ("Practical Hygiene," p. 371.
Or, adding 10 lbs. for clothes on person..	82 „	
In Campaign of Italy, 1859.....	*67¾ „	As given by Col. Brialmont ("La Fortification Improvisée").
Or, adding 10 lbs., as before	77¾ „	

Austrian,

Weight of arms and equipment, 1869	49 lbs.†	English.
Adding 10 lbs. for clothes on person	59 „	

* Made up as follows :—	kilo.	lbs. „
Arms and necessaries	20	44
60 cartridges	2·4	5·28
Tente d'abri, blankets, &c.	5·	11
Rations for four days, without meat	3·40	7·48
	30·8	67·76

† Made up as follows :—		lbs.	oz.
Kit, including great coat		15	3½
Accoutrements.....		10	4½
Canteen and cooking-tin		4	0
Provisions		3	11
Rifle { Werndl, with 72 cartridges		16	8
Rifle { Wanzl, with 60 do. 15 lbs. 4 oz..			
Total with Werndl rifle.....		49	11
Ditto with Wanzl do.		48	

BELGIAN.

Weight of arms and equipment.....	55 lbs. English.
Adding 10 lbs. for clothes on person, as before	65 „

Of this I have no detail.—G. G.

APPENDIX NO. VI.

Transport of Tools for One Brigade.

Lieut. Blood, of the R.E. Train, has kindly supplied me with the accompanying memorandum:—

"For transport of the intrenching tools for one brigade only of the "light pattern, one wagon would be sufficient. The tools would be as "follows:—

Picks	380
Shovels.....	380
Total.....	760
Spare helves for—	
Picks.....	30
Shovels.....	30

"The detachment of R.E. Train would be as follows:—

N. C. O. mounted.....	1
Drivers	2
Shoeing-smith	1
Sappers	4
Total men	8
Horses—	
Riding	1
Draught.....	4
Total horses ..	5
Wagon	1

"The wagon would require to be specially fitted up, and when "loaded would weigh as follows:—

Wagon	14 cwt.
Tools	18¾ „
Camp equipment, &c.	2 „
Total	34¾ „

"This would not be too much for four horses; in fact, a properly "constructed wagon with this load could go anywhere with infantry."

"S. M. E., "B. BLOOD.

"5th May, 1870."

Evening Meeting.

Monday, June 27th, 1870.

W. STIRLING LACON, Esq., in the Chair.

NAME of MEMBER who joined the Institution between the 20th and 27th June, 1870.

ANNUAL.

Wright, W. H., Lieut. R.A. 1*l.*

The CHAIRMAN: I wish to announce that the meeting this evening concludes our session of lectures and papers for the year. It has been on several occasions acknowledged by the Minister for War, and also by the First Lord of the Admiralty, who have occupied the chair successively at our Annual General Meetings, that this Institution holds a place midway between the Parliament and the Government that is to say, that subjects which cannot be discussed either in the House of Commons, or in the bureau of the Minister apart from questions of party policy or of administration, are discussed in the theatre of this Institution free from those questions. It is for this reason, therefore, that the Council specially invite members who have taken up any subjects connected with naval and military science, to bring them forward, in order that they may be discussed in the theatre of the Institution, and afterwards circulated, by means of the *Journal*, to members of both services in all parts of the world.

I now call upon Captain Morgan to read his paper "On a very Heavy Breech-loading Gun of Novel Construction."

A PROPOSAL FOR A VERY HEAVY BREECH-LOADING GUN OF NOVEL CONSTRUCTION.

By Captain J. P. MORGAN, Royal Artillery.

IN making a proposal for a new gun it is necessary to prove three things:—

1. That a new gun is needed.
2. That it is not advisable to make it on any of the present systems.
3. That it ought to be made on the system I now propose.

I. *Necessity for a very Heavy Gun.*

In order to shew the necessity for a very heavy gun, I cannot do better than quote from the very interesting book on *Our Ironclad Fleet*, by Mr. Reed, the Chief Constructor of the Navy. Talking of the "Hercules" he says, at page 30:—

The total thickness of iron (neglecting the girders and frames) is 11½ inches, and of this 9 inches are in one thickness; the teak backing has a total of about 40 inches. The trial at Shoeburyness of a target constructed to represent this part of the ship's side proved that it was virtually impenetrable to the 600-pounder gun, and perhaps no better idea of the increase of the resisting power of the sides of our ironclads can be obtained than that derived from a comparison of the 68-pounder gun, which the "Warrior's" side was capable of resisting, with the 600-pounder tried against the "Hercules" target. But the limits of the thickness of armour carried must not be considered to have yet been attained. Coast defence vessels and rams are being built to carry 11 and 12-inch armour; the new turret ships "Thunderer" and "Devastation," lately designed, will carry quite as great thicknesses, and ships have been designed for sea-going purposes, and may yet be constructed, which are to carry even 15 inches of armour. There can be little doubt that, as improvements are made in the manufacture and working of heavy guns, corresponding additions will be made to the resisting powers of ironclads built. It is hardly possible to foresee in what way the competition between guns and ships will terminate; but, having the experience we possess of the successful accomplishment of what only a few years ago were regarded as impossibilities in the construction of ironclads, it would be folly to set a limit to the results that will be attained in the future. The Admiralty have long been in possession of a design for a turret-ship with sides plated with 15-inch armour, and turrets with 18-inch armour. I have also prepared outline designs, not on extravagant dimensions, to carry 20-inch armour, both on broadsides and on turrets.

Mr. Reed also quotes from Captain Scott, R.N., in a foot note, page 58:—

At the Royal United Service Institution in 1863, Captain Scott made the following interesting remarks:—"The size of the gun is of vast importance, more than is generally assigned to it, and for this reason,—20 guns, each a 1-pounder, are fired at a target 1½ inches thick, and produce no effect; one gun, a 20-pounder, is fired and smashes it; the velocities in both cases being equal, in both cases the same amount of metal is used; and on this principle an official record of experiments at Portsmouth states that one 68-pounder produced more destruction than five 32-pounders. Arguing thus, it appears that one 150-pounder is more effective than ten 68-pounders, one 330-pounder is equal to seven 150-pounders, and a broadside of three 330-pounders is more destructive than 10¼ "Warriors." In this last statement the "Warrior's" broadside is taken at twenty 68-pounders.

Arguing thus, I may say that a ship carrying two 1,200-pounders would be nearly equal to one-half of the British Navy.

II. *The present Systems of Gun Manufacture.*

A very heavy gun, therefore, being necessary, let us examine the sufficiency of the present systems for producing it.

1. Preliminary Remarks.

a. Longitudinal Strain.

The two great strains to which a gun is subjected are the longitudinal and the circumferential. Of these, the latter is undoubtedly the greater, but the former is that which has given most trouble to know how to meet it.

Mr. Rigg, C.E., in the end of 1867, read "A paper on the connexion between the Shape of Heavy Guns and their Durability," before the Society of Engineers, in which he shows that the mass of the breech is of great importance in meeting the difficulty.

He says, at page 3 :—

If the breech, or that portion of the gun behind the base of the bore, be heavy, it opposes a considerable resistance to the shot, absorbs the force of the blow, and so reduces the longitudinal strain upon the barrel. If the breech be light in weight, the first impact is delivered upon a mass of metal, perhaps not greater than the shot itself. The breech in this case does not absorb the blow, but transmits it at once to the barrel. Time is not given for so heavy a mass to begin its recoil; the longitudinal strain is greater than the tenacity of the metal will bear, and fracture is inevitable. It may happen that the breech is blown off, or that the barrel bursts, but in either case it is the double cross strain that causes great weakness, and any means by which either of them can be reduced will not fail to be beneficial.

The relief which a heavy mass affords in receiving and absorbing the force of a blow admits of many familiar illustrations. The different feelings with which a heavy or a light stone may be struck when held in the hand are well known, but perhaps the most singular instance of this law may be found in a case which excited much wonder in the last generation, namely, that of a man who was accustomed to exhibit himself sustaining a very heavy stone on his chest while lying on the floor; several large sledge hammers were freely used upon the stone, but although so much force was applied, there was no injurious effect upon him who submitted to such an ordeal. The relief afforded by simple weight in these examples gives just the same immunity to a gun. Such a conclusion would lead to the inference that the greatest durability will be associated with the heaviest breech, and the following examples will prove this deduction to be well founded.

Mr. Rigg gives illustrations of various guns in support of this idea, and mentions specially that at the siege of Charleston—

One gun, a 30-pounder, showed most extraordinary and unique powers of endurance. Through some accident in its construction, the wrought-iron reinforce was shrunk firmly on the breech, and not on the body of the gun; consequently its weight and inertia became available to resist the first impact of the discharge; the longitudinal strain was thereby diminished, and the gun relieved from much of its usual load .....

After firing 4,606 rounds, this gun burst into seven pieces .....

Mr. Rigg also quotes from Major Palliser as follows, page 11 :—

The same idea lurks in the following remarks by Major Palliser, although the last sentences contain the gist of the whole argument :—"There are two ways in which a "gun can burst, viz., by the bursting of the barrel, or by the end being blown off. "In an ordinary cast-iron gun, the whole longitudinal pressure acts on the end of "the bore. If the bore be 8 inches diameter, this pressure will, in round numbers, "be distributed upon 50 square inches. If, however, the gun be bored up to "13 inches and lined with a barrel 2½ inches thick, the longitudinal pressure will "act upon 50 square inches, as before, but will be transferred to a surface of about "130 square inches; and thus the longitudinal strength of the gun becomes more "than doubled. In fact, every way of regarding the subject shows that the circumferential strength should be applied internally, and the longitudinal strength should "be borne by the outside; and this is precisely the reverse of the principle upon "which the wrought-iron guns of the service are made."

Mr. Rigg adds—

The idea of separating the forces into circumferential and into longitudinal is very correct in theory, and practical, as well as the assignment of a special share of duty to each part of the gun .....

In conclusion, it is evident, that there can be no reason why English guns shall not always reliably exhibit the same endurance that was shown by the solitary Parrott gun that bore 4,606 rounds. It is simply a question of correct principles of construction, and if it be desired, still further to enhance the powers of the guns

which Major Palliser has begun so well, the question of longitudinal strain is that to which attention must be given.

These remarks of Mr. Rigg's are very valuable, and it is to this very question of longitudinal strain that my proposition is mainly directed. Allow me, however, before stating what my proposition is, to show you that the longitudinal strain, in addition to the injury it causes in itself, also injuriously affects all the endeavours in the present systems of gun manufacture to meet the

β. Circumferential Strain.

In Fig. 1, the solid lines represent the inner and outer surfaces of a hollow cylinder before extension—the dotted lines after extension. Supposing the most favourable case of the metal being perfectly dense, the area between the two solid lines will equal the area between the two dotted lines; and the area between the inner solid line and its dotted line will equal the area between the outer solid line and its dotted line. But as the outer area is further removed from the centre than the inner, its length is greater, and consequently its breadth less in proportion. The absolute amount of extension of the outer surface will thus be to that of the inner inversely as their radii. Owing, however, to the greater length of outer area, it is capable of extending more instead of less in proportion to the radius. The total proportionate extension therefore of outer to inner surface is inversely as the squares of their radii; and as the tension increases directly with the extension, the tension or useful effect decreases as you recede from the centre, and is inversely as the square of the distance from the centre.

If the metal be not dense, the decrease is even more rapid than this.

Fig. 2 represents the tensions at different distances from the centre on the principle above stated. The horizontal distances are the distances from the centre, the vertical distances are the tensions. Notice how rapidly the tension diminishes as the thickness increases when the radius is small.

The following equation shows the actual amount of useful effect which can be obtained by one thickness of metal as compared with what it would be if all the metal could be made to do its work:—

Let r be the radius at any point,
t be the tension at that point,
a be the internal radius,
b be the external radius,

$$T \text{ (total useful effect)} = \int_a^b \frac{m}{r^2}\,dr$$

$$= -\frac{m}{r} \text{ between limits } a \text{ and } b$$

$$= m\left(\frac{1}{a} - \frac{1}{b}\right) = \frac{m}{ab}(b - a).$$

Fig 2

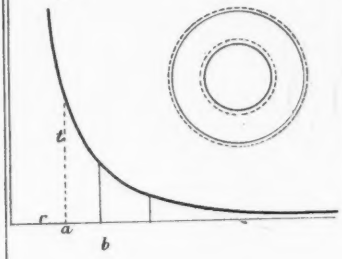


Fig 1.

Fig 5.

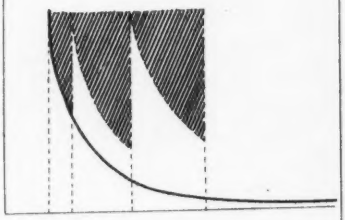


Fig 3.

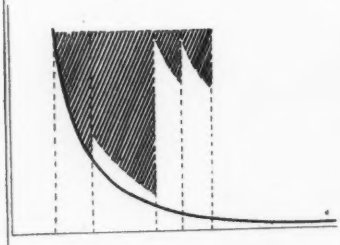


Fig 6

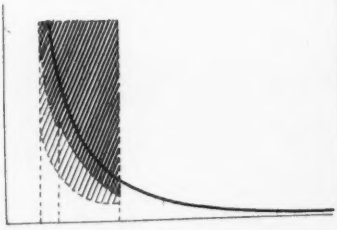


Fig 4.

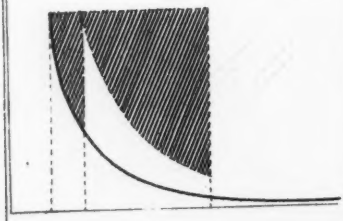
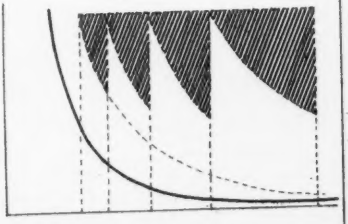


Fig 7.



J.Jobbins

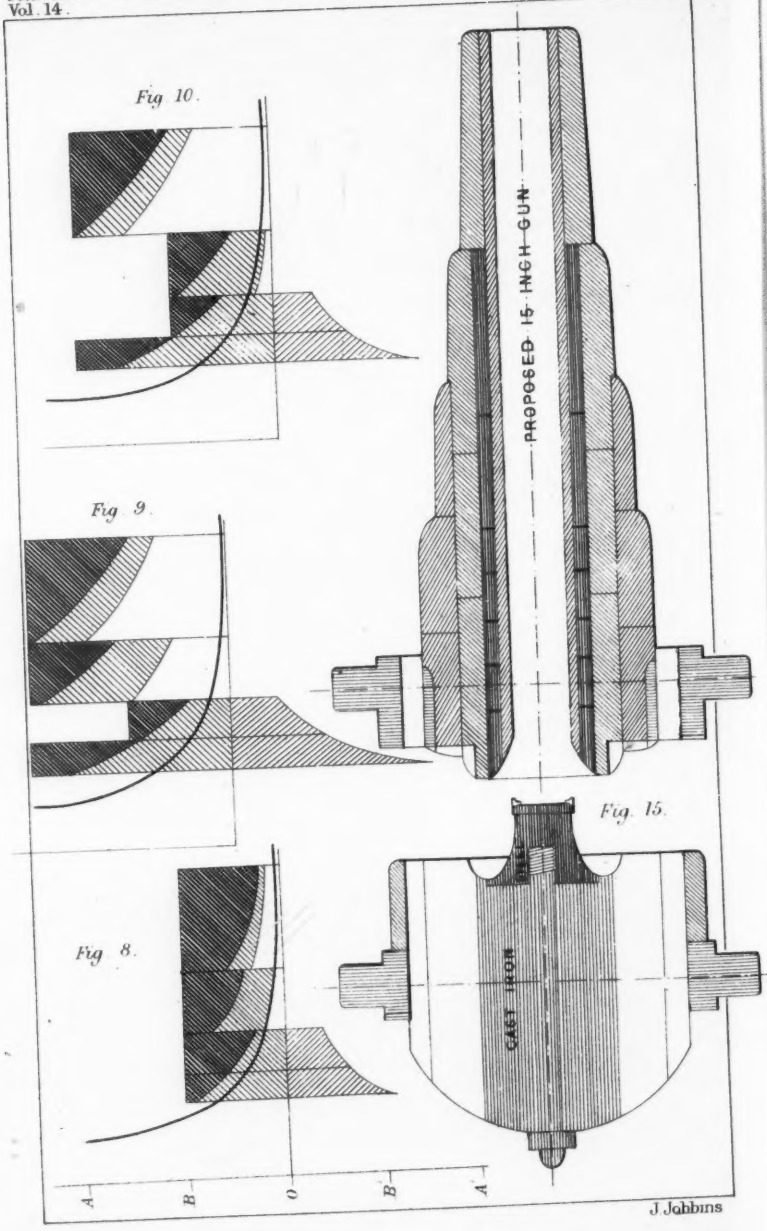


Fig. 10.
Fig. 9.
Fig. 8.
PROPOSED 15 INCH GUN.
Fig. 15.
CAST IRON
A
B
O
B
A
J. Johbins

If the tension were uniformly equal to that at a, it would give a total strength $\frac{m}{a^2}(b-a)$. Therefore $\frac{\text{actual tension}}{\text{total strength of metal}} = \frac{\frac{m}{ab}}{\frac{m}{a^2}} = \frac{a}{b}$. So that the value of any hollow cylinder may be represented by the ratio of its internal to its external diameter multiplied by its thickness. The more nearly this ratio is unity, the greater will be the proportion of work obtained; also, as the calibre increases, so may the thickness be advantageously increased.

By taking the internal radius as the unit of thickness, we can readily see the very small addition of strength which is gained by increasing the thickness. A thickness of $\frac{1}{2}$ calibre gives a strength of $\frac{1}{2}$ of $\frac{1}{2}$ calibre; a thickness of 1 calibre gives a strength of $\frac{1}{2}$ of 1 calibre or $\frac{2}{3}$ of $\frac{1}{2}$ calibre. A thickness of $1\frac{1}{2}$ calibres gives $\frac{3}{4}$ of $\frac{1}{2}$ calibre, so that we have $\frac{1}{2}$ for the first $\frac{1}{2}$ calibre, $\frac{2}{3} - \frac{1}{2}$ or $\frac{1}{6}$ for the second $\frac{1}{2}$ calibre, $\frac{1}{1.2}$ for the third, and so on; the total is therefore $\frac{1}{2} + \frac{1}{2.3} + \frac{1}{3.4} + \frac{1}{4.5} +$ *ad infin.* for an infinite thickness. Now, as the sum of this series can never reach unity, it follows that, even with an infinite thickness, we can never obtain as much useful effect as we shall from $\frac{1}{2}$ calibre of thickness if all the metal could be made to do its work. This law is fatal to a very heavy gun ever being made of one homogeneous piece of metal.

2. Armstrong Guns.

It was for the reason above stated, that Sir William Armstrong gave initial tension to the successive coils adopted in his system, so that, if properly arranged, they should have all their interior surfaces at their greatest tension at the moment of maximum strain. The great amount of strength gained by this method will be seen in Fig. 3, which represents a 9-inch gun, on the Armstrong plan, with all the coils extended so that the inner surfaces are all at the elastic limits of the iron. The area below the continuous curve is all the strength that could be obtained if the whole gun were of one piece. The areas between the continuous and discontinuous curves are the additional strengths obtained by initial tension. It will be noticed that more waste power is rescued, as the distance from the centre increases. But this also involves greater initial tension; and for this purpose, at one calibre thickness, the initial tension must be eight-ninths of the strain the coil is to bear. If so much initial tension as this is put on, there is a danger on the one hand, of overshooting the mark and over-straining the coil so much that it may break—and this was actually the case in a 600-pounder which burst one of its coils, while the barrel and all the other coils remained sound. On the other hand, if too little tension be put on, it may so happen that the iron beneath is more compressible than usual, and the greater part of the tension may be absorbed without compressing the bore. These two dangers both increase as the thickness of the metal increases; and, for this reason,

Major Palliser's remarks are very appropriate, viz., that the circumferential strength should be obtained as near the bore as possible. This useful maxim, however, cannot be carried out in the Armstrong gun, on account of the breech-piece, which surrounds the most vital point at the powder chamber, see Fig. 11. The breech-piece has its fibre arranged longitudinally, for the sake of longitudinal strength, and gives in consequence, circumferentially, only half the strength coiled iron would give, inasmuch as iron across the fibre is only half as strong as it is along the fibre. The breech-piece, also, is very thick, and undergoes a still further loss of strength on that account. Altogether, we can only count on one-half of the tension of bar iron for the inside of the breech-piece, and something like one-sixth or one-eighth for the outside, and on a total strength of not much more than one-fourth of the useful effect of the iron. In Fig. 3, the shaded portion of the diagram shows how much strength is lost.

When we come to the outside coils, the conditions are apparently much more favourable, for there seems to be very little strength lost. But these coils are far removed from the bore, and, as we have seen, there is not the same certainty of their doing their work as there would be if they were near. Also, since the bursting of the 600-pounder, the initial tension has been very much reduced, and the same amount is not now given, as shown in the diagram. Owing to the large diameter of these coils, they are expensive to make, so that this is not an economical way of getting up the strength.

Another fault may be added. The longitudinal strain is, to a considerable extent, borne by the steel barrel, contrary to Major Palliser's principle and Mr. Rigg's objection to the cross strain on the bore. It is, however, to be remembered that, at Elswick, these guns were first made with a loose end, which avoided the cross strain on the bore, and threw all the longitudinal strain on the breech-piece. The advantage thus gained is, however, very questionable, for if the longitudinal strain be not partly borne by the steel tube, it is necessary to have a thicker breech-piece, which leads to even greater errors, as we have seen. None of these guns are now made with loose ends, but they are sometimes made at Elswick with thinner breech-pieces.

3. Fraser Guns.

a. With one Triple External Coil.

Fig. 12 shows the first pattern that was made without a longitudinal breech-piece. So far, this is a very important step; for if the gun be all coiled iron, it will much better resist the most dangerous circumferential strain. In the construction of this gun there has evidently been a due regard paid to longitudinal strain, as well as to economy, for there is a good thick steel tube, as well as a very thick coil, brought to bear on it. If the thick coil be properly welded, the longitudinal strain may be fairly considered as met.

But mark the other objections which this involves. Owing to the great thickness of the external coil, $\frac{3}{4}$ of its useful effect only can be

Fig 11.

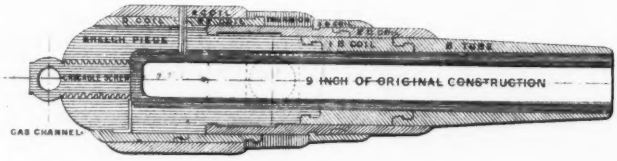


Fig 12

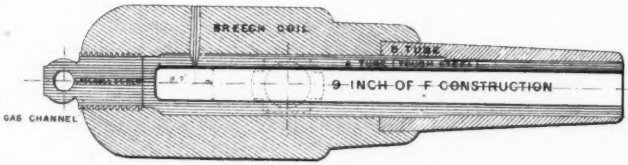


Fig 13

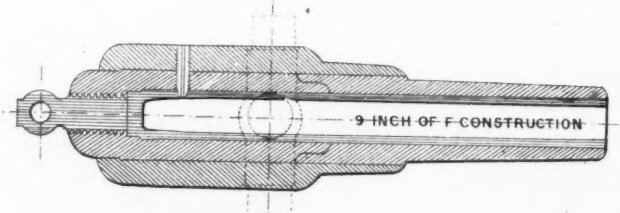
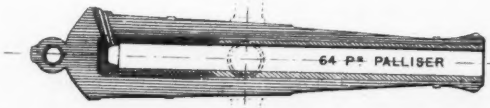


Fig 14



J. Jobbins

obtained for circumferential strength, seeing that the internal and external diameters are as 2 to 5. Also, on the one hand, if the welds are not properly made, there will be a deficiency of longitudinal strength; and, on the other, if to make sure of longitudinal strength, the iron be strongly heated, there is a danger of the iron becoming deteriorated by overheating. These are the two dangers which have to be avoided in manufacture, and though, with one exception, they may have been successfully avoided, a great risk is run should there be any carelessness, especially when it is considered that there is only one coil to depend on.

On the subject of overheating iron, Dr. Percy says, in his Metallurgy, Iron and Steel, p. 8–10:—

The crystallisation of iron has excited much attention, especially amongst engineers, and although much has been talked and written about it, yet no small confusion respecting it still prevails. However, a careful examination of the subject will tend to remove this obscurity. Bar iron acquires a largely crystalline structure by long exposure to a temperature which, though high, is yet very far below the melting points of the metal. On the application of a certain amount of heat, the particles have sufficient freedom of motion to arrange themselves in crystals. We have previously had a striking illustration of this fact in the annealing of sheet zinc, at a temperature bordering on, yet sensibly below its melting point. Hence we can readily understand why iron, which has been frequently and strongly heated, or iron which has been forged into large masses, and which must necessarily have been subjected during a considerable time to a high temperature, should tend to become largely crystalline in structure. The operation of hammering iron while strongly heated and during cooling, to a certain degree will obviously interfere with the action of the forces which determine crystalline arrangement, and may consequently be expected to diminish the size of the crystals. But in the case of large masses, it will be difficult to affect the metal far below the surface, unless a very heavy hammer is employed, and very powerful blows are applied; and even then it is hardly possible to conceive that uniformity in the size of the crystals should be produced through the mass. For, when the exterior may be cooled down to redness, the interior must still be at a much higher temperature, it may be white hot; so that on subsequent cooling, after the cessation of the blows, the particles in one part of the mass will be in a condition to assume a more largely crystalline structure than those in another part. It is this which constitutes the difficulty in large forgings; and it cannot be overcome by continuing the hammering until the metal in the interior is sufficiently reduced in temperature to prevent the formation of large crystals in that part; for if the metal on the exterior were hammered at too low a temperature, as would certainly be the case in the condition supposed, it would become brittle and tender. It must be borne in mind that these remarks relate to iron, and not to steel, or iron containing any sensible proportion of carbon. With reference to the size of the crystals, it should here be stated that the presence of phosphorus favours the formation of large crystals; and this element occurs in most commercial varieties of British iron. The rapid cooling of large forgings by immersion in water might be expected to render the interior less largely crystalline.

When iron is hammered cold, especially in various directions, the crystals of which it consists will obviously become more or less disaggregated, and, therefore, the strength of the metal will be diminished. The larger the crystals, the more easily will the iron break; for, as fracture will occur in the direction of least resistance, which is that of the cleavage planes, and of the planes of junction of contiguous crystals, it will be facilitated in proportion to the size of these planes. I have buttons of fused iron, in which the crystals are so large, that the cleavage planes extend completely across the fracture. On the other hand, when the crystals are comparatively small, they are, so to speak, more interwoven with each other; there are no large cleavage planes, and, consequently, there is less tendency to fracture

Whether the foregoing considerations be correct or not, it is well established in practice, that largeness of crystal in a bar of iron indicates facility of fracture.

Mr. Kirkaldy's 56th concluding observation on experiments on wrought-iron and steel is :—

Iron is injured by being brought to a white, or welding heat, if not at the same time hammered or rolled.

My own experience corroborates these views. While employed in the duty of inspecting the conversion of guns at Elswick, on Major Palliser's system, a portion of one of the tubes got accidentally overheated, and the fault was not discovered until the tube was tested by water pressure of 3 tons to the inch before being put into the gun. It then broke into two pieces, and on examination the fracture was found to be largely crystalline, as described above by Dr. Percy.

There is another objection, which must always hold good against these very thick coils. It is claimed in the Armstrong system that, if the interior of a coil be cooled more quickly than the exterior—and this is always done by water from the centre during the building up of the gun—the interior will be in a state of compression, while the exterior is in a state of extension, so that a more regular succession of tension obtains than by steps from coil to coil. The increased temperature from which the coil is cooled after forging will make this law act more powerfully in the case of the Fraser coil. It will cool from both outside and inside, so that both outside and inside are in a state of compression, while the interior is in a state of extension. The tendency is thus to separate into two cylinders, the outer of which will not support the inner.

This tendency is very much increased if, after once cooling as above, it be again heated and cooled. For the second heating commences at the surface, and causes it to swell out before the interior is softened. The internal extended portion remains as it was, and, on the whole mass again cooling from the surfaces, the bad effects double themselves. I have seen a case of this. A large Morrison hammer was being made. A Saturday night intervened, and it was allowed to cool in a half-finished state. On Monday it was again heated and completed, but on being turned, it was found to contain a hole in the interior so large that it had to be condemned. This second heating happens in the thick Fraser coil; for the trunnion-piece, with its fore and after coil, having been made separately, are all allowed to cool. They are then joined together, all heated a second time, and welded into one piece.

If we consider all these various objections, it is not surprising that one of these guns should have burst at proof.

β. Pattern with two External Coils.

Fraser's latest pattern, Fig. 13, is perhaps as good a pattern as is ever likely to be arrived at for 9-inch guns, unless the system which I am about to propose, and which introduces an entirely new principle, be adopted. It has no prominent faults. All the difficulties are so evenly balanced, that it is hardly possible to improve on it. None of

them are, however, removed, and any serious fault in manufacture might bring one or other into prominent play. Instead of the thick coil, we have two thinner coils. Thus, very much strength is gained by the second shrinkage, as shown by a comparison of Fig. 5 with Fig. 4. There is much less risk from overheating, and from second heating, for the inner coil is thinner, and not joined on to the coil in front. The outer coil is still heated a second time; but not being thick, and, besides, being outside, the danger is not so great. There is a slight disproportion in the increasing thickness of the coils, as shown in the diagram. The first might be slightly thinner with advantage, if circumferential strength only be considered, but this might detract from the longitudinal strength.

Captain Stoney, R.A., Assistant-Superintendent Royal Gun Factories, appears to be aware of the risk run, for he says in vol. vi, page 411, of the "Proceedings of the Royal Artillery Institution:"—

> With respect to the precise pattern for future construction, it would perhaps have been the safest course to have continued firing No. 332 gun (of the pattern under consideration), and then if it did not blow its breech off (its tube being so thin), or burst explosively without giving ample warning, to adopt it as the pattern for all the heavier natures. The authorities, however, have decided on constructing 7-inch and 8-inch guns as before, on the No. 368 type (the pattern with triple coil), but to make 9-inch guns and upwards on the 332 type.

Thus the principle is recognised that the heavier the gun, the greater the necessity for coming to true scientific principles of construction; for, as the size of the gun increases, our power is tested to confine and restrain the enormous pressure which is called into play. With the heaviest gun no fault can be tolerated. Though I admit that the Fraser gun is well suited for 9-inch guns, and guns even much bigger may be made on this principle, especially if the pressure of the gunpowder be reduced, yet I do not believe that it is capable of supplying the heaviest gun that can be made. It may stand up to 1,000-pounder, but I am doubtful of its being able to exceed this, for the following reasons.

From Captain Stoney's remarks it may be inferred that, on account of the longitudinal strain, it will not be safe to reduce the proportion of thickness of the first coil. It will be necessary rather to increase it; for, in order to maintain the velocity, the pressure of the gunpowder on each square inch of the base of the shot must of necessity increase, on account of the column of metal in front of each square inch of base increasing in length. With the 1,000-pounder, therefore, the actual thickness of this coil will be at least equal to that of the triple coil, which failed in the 9-inch gun. The proportion of power gained will thus be reduced. The danger, too, of Dr. Percy's law of crystallisation coming into play will increase. External compression will manifest itself, and the tendency to split into two cylinders.

4. Palliser Guns.

These guns will never be able to compete as heavy guns, but they

afford a wonderfully practical illustration of the value of the laws I have noticed. Instead of having the outside contracted on the inside, the inside is expanded on the outside, and this can be done by using wrought iron for the bore, see Fig. 14. If we take a 32-pounder, whose internal and external radii are roughly 3 and 10 inches respectively, we have a strength of $\frac{3}{10}$ of 7, or 2 inches of cast-iron. But if the internal radius be bored up to 5 inches, and a wrought-iron tube 2 inches thick be put in place of the cast-iron bored out, we have, for the strength of the remaining cast-iron, $\frac{5}{10}$ of 5, or $2\frac{1}{2}$ inches. So that the cast-iron is actually stronger than it was before. The strength of the wrought-iron tube has to be added, so that these guns are probably at least twice as strong as they were before conversion for circumferential strain. See Fig. 6, where the unshaded portion represents the strength before conversion. The slightly shaded part represents the gain by conversion.*

III. *New Proposed Pattern.*

I have now to examine the pattern proposed by myself, and to show that it is the system which ought to be adopted for very heavy guns.

The principle consists in receiving the longitudinal strain on a solid block of metal not rigidly connected with the rest of the gun. There is thus no longitudinal strain on the gun, and, consequently, no cross strain on the bore. Mr. Rigg's views are thus perfectly met. Major Palliser's maxim is also fully carried out; for, the longitudinal strain being entirely removed, it is quite easy to turn our whole attention to getting circumferential strength as near the bore as possible. The iron can be used in the best possible condition, and under the best form of arrangement. I have already noticed that near the bore the coils ought to be thin, but that they may increase in thickness towards the outside. A reference to Figs. 7 and 15 will show how this is carried out. About $\frac{1}{4}$ only of the useful effect of the iron is lost. In addition to this the iron need not be over-heated. All the coils may be made short, and the inner ones could be well hammered, which is a matter of great importance. They could even be rolled out like tyres of railway wheels. The outer coils, which are thicker, could, without danger, be on the side of under-welding rather than over-welding. Their shortness would be favourable to perfect manufacture, and at least the two ends of each coil would always be sound. No second heating is necessary, so that there would be no tendency to form cavities in the iron, or to split into two cylinders.

Breech Loading.

In addition to the advantage of great strength, breech-loading

* The diagram is to be considered as representing strength, and not elasticity. Cast iron is quite as elastic as wrought iron, or more so; but it is probable that wrought iron, owing to its malleability, allows the tube to be extended beyond its elastic limits without rupture or great loss of strength.

comes in as a most important element in the gain which will be obtained by this method of construction.

Lead-coating is the only method that has been used in our service with breech-loading guns, but it is not a necessary consequence; for we find that on the Continent, where breech-loading prevails, though the Russians, Prussians, and Austrians use lead-coating, the French do not. In deciding between these two systems, it is a point of great importance to know what is the maximum initial pressure of gunpowder in the bore. One of the chief dangers, in using lead-coated projectiles with very heavy guns, will be the stripping of the lead. It can hardly be doubted that the moment of first starting is that at which this is most likely to take place, when the shot begins to take the grooves, and when the pressure is the greatest. Not only does the pressure increase, but another law acts adversely; for the mass rotated increases as the cube of the calibre, while the lead-coated surface which produces rotation increases only as the square of the calibre. We know, however, that lead-coating is safe with a 7-inch gun and our present gunpowder. If the initial pressure can be reduced to one-half, a 15-inch gun could be made as safe in this respect as a 7-inch gun at present is. A Committee is now sitting on the question of gunpowder, and has already issued a preliminary Report showing that, by a modification of the size and shape of the grain, the initial pressure can be reduced to about one-half. This is for smooth-bore guns and windage. It would be very useful to know whether the same results hold good with lead-coated projectiles where there is rifling and no windage. The gun I propose would be a useful means of determining this; for, as designed for service, it will fire out its breech at the rate of 15 miles an hour. By reducing the size of the breech to $\frac{1}{4}$, it could be made to retire along a railway at the rate of 60 miles an hour; and, while it retired, a record could be obtained from it on a revolving cylinder, which would give a curve, continuous throughout, from which the spaces described in given times could be measured, and so the velocities and pressures deduced.*

Before adopting rifling by lead coating with a very heavy breech-loading gun, it would be necessary to know what is the initial pressure under the exact circumstances to be used. The initial pressure should be as much reduced as is consistent with the maintenance of initial velocity. In itself, however, lead coating has the effect of increasing the initial pressure, for it gives no relief by windage, and the compression and friction of the lead coating give considerable retardation, so as still further to increase the pressure. There is also to be added the resistance which is produced by the necessity of having an uniform twist. All these causes act, not only in a degree which can be mathematically calculated, but also, in an uncertain degree, by affecting the explosion of the gunpowder, so that nothing but experiment can be depended on.

Lead coating has one very great advantage. It is the best method of preventing windage, and, as windage has the effect of scoring the

* This was suggested to me three years ago by the Rev. F. Bashforth, Professor of Mathematics to the advanced class of Artillery Officers at Woolwich.

bore of the gun to such an extent as to render the gun unserviceable from this cause alone, this is a matter of some moment. It would especially be an advantage with a very strong and heavy gun, such as the one I propose, for, as a rule, the bigger the gun the greater the scoring; and if the strength of the gun were such that it would wear out in this manner before bursting, this would be the point most requiring to be attended to. No doubt with breech-loading, greater facility would be given for stopping the windage than in muzzle-loading guns, by using a tight-fitting wad between the powder and shot, but it would not do this so effectually as lead coating.

At present windage has one advantage, owing to the difficulty of providing a suitable fuze for breech-loading guns. It is not probable, however, that this will long be a serious objection, now that attention has been directed to the difficulty. Captain Nolan and myself have proposed a method of using muzzle-loading fuzes with breech-loading guns, by making a channel through the projectile, so that the flash of the discharge may pass through and ignite the fuze.

Sir William Armstrong last year, in his address as President of the Manufacture Institution of Mechanical Engineers, at the Newcastle meeting, says :—

Krupp and Whitworth, both great names in gunnery, though differing widely in their views in other points, agree in this, that steel is the right material for the entire gun. I, on the other hand, have always advocated wrought-iron in the form of welded coil for the chief mass of the gun, limiting the use of steel to the internal tube, which has abrasion to resist, as well as tensile strain. The expression of my opinions upon this point may, probably, not be considered impartial, but I will, nevertheless, state the grounds upon which my preference of wrought-iron, thus applied, is based.

It has been found both in Elswick and Woolwich guns, that whenever failure takes place, it almost invariably originates with that part which is made of steel. It is the steel tube which is nearly always the first to crack. So also when the vent-pieces, or closing blocks of the breech-loading guns were made of steel, their fracture was alarmingly frequent, but since wrought-iron has been substituted, such occurrences are rare. The conclusion, therefore, at which I long since arrived, and which I still maintain, is, that, although steel has much greater tensile strength than wrought-iron, it is less adapted to resist concussive strain. This conclusion is in strict harmony with the fact, that armour-plates made of steel, have proved on every occasion of their trial, greatly inferior to plates of wrought-iron. The experiments which I made some years ago, on the toughening of steel in large masses, by immersion, when heated in oil, led me to expect that this fragility would be obviated by that process. And I felt sanguine that I should be able by such treatment to produce steel armour-plates of extraordinary resisting power. An armour-plate of steel was accordingly manufactured for experiment, and was tempered in a large bath of oil. Its quality was tried by test pieces cut off after tempering, and proved by tension and bending. The result showed a very high tensile strength, combined with so much toughness that I was unable to match its bending power by any sample of iron I could compare with it. The plate was then sent to Portsmouth for trial, in the fullest confidence of its success, but two shots from a 68-pounder sufficed to break it in various directions, and it was justly pronounced a failure. With these experiences before me, it is impossible that I can hold any other opinion than that the vibratory action attending excessive concussion, is more dangerous to steel than iron, and were it not necessary to provide a harder and more homogeneous substance than wrought-iron for the surface of the bore, I should entirely discard steel from the manufacture of ordnance.

I do not wish to trench on the much vexed Armstrong and Whit-

worth controversy, but, in investigating this subject, I have arrived at a very curious result. Fig. 8 represents my gun made wholly of steel. The lower margins of the faintly shaded portions give the strains on the gun in its natural state. Above the horizontal line is the tension, below the compression. The tension must balance the compression, and therefore, on the supposition that within the elastic limits the tensile and crushing strengths are equal, the area above the line is equal to that below. OA and OA′ are the elastic limits of iron; OB and OB′ of steel. The compression area is necessarily limited, so as not to exceed the elastic limits of the metal at the bore. The amount of tension must therefore also be limited, and the result is, that, when the whole are extended, the outer coils are by no means strained to their utmost. If the crushing strain were greater than the tensile strain, the conditions would be more favourable; but, in the case of wrought-iron, where the crushing strain is less, the conditions would be less favourable. It would not, therefore, be advisable to discard steel entirely from wrought-iron guns. There must be some strong metal to bear the crushing strain which initial tension brings on the bore. It is not necessary, however, that the steel be at the bore itself. It may be used much more advantageously in the second course.

Fig. 9 represents my gun with the second course of steel in the region of the powder-chamber. The result shows much greater strength. In calculating the strength, it is necessary to multiply the steel area by 4, as the elasticity is only half, while the tenacity is twice that of wrought-iron.

Fig. 10 shows both 2nd and 3rd courses of steel. The result is equally satisfactory.

The absolute mathematical strengths of these three constructions may be given, in the order in which they have been considered, as 9, 8, 10. This, however, does not take into account any errors of manufacture which will tell more severely against steel than iron, as an error of $\frac{1}{10,000}$th in dimensions represents a loss of 1 ton per square inch in iron, and 4 tons in steel.

In the all-steel construction there would be no gain by increasing the thickness of metal beyond $1\frac{1}{2}$ calibres. It might be made in two pieces, the inner $\frac{1}{2}$ calibre, and the outer 1 calibre thick, giving $\frac{1}{2}$ of the useful effect of the metal. The explosion would thus be resisted by steel, equal in value to $1\frac{1}{2}$ times the dimensions of the bore, and thus by working the steel up to 20 tons, or its elastic limits, the pressure in the bore might be 30 tons, if gradually applied. A large reduction, however, has to be made on account of the suddenness of the strain, as shown in the following calculation:—

Let P = the pressure in the bore suddenly applied, *i.e.*, uniform during the time of expansion.

r = radius of bore.

s = space described from the centre by the mass of metal m, in the time t.

T = tension caused by the extension of the metal, and which, varying with s, may be put $= \mu s$.

We have—

$$P = \frac{T}{r} + m\frac{d^2s}{dt^2}$$

$$= \frac{\mu s}{r} + m\frac{d^2s}{dt^2}$$

$$2\frac{ds}{dt}\frac{d^2s}{dt^2} = 2\frac{P}{m}\frac{ds}{dt} - 2\frac{\mu s}{rm}\frac{ds}{dt}$$

$$\left(\frac{ds}{dt}\right)^2 = 2\frac{P}{m}s - \frac{\mu}{rm}s^2$$

$$= 2P\frac{T}{\mu m} - \frac{T^2}{\mu r m}$$

Now, when T is a maximum $\frac{ds}{dt} = 0$

$$\therefore 2P = \frac{T}{r}$$

i.e., in accordance with the rule laid down by engineers, we can only meet half the pressure when it is suddenly applied.

The Gunpowder Committee gives, with the new gunpowder, the maximum pressure in guns of 8 inches calibre as 15 tons per square inch, and not suddenly applied. Allowing it, however, to be suddenly applied, to cover any margin of error in calculation or manufacture, the result is that a steel gun would be worked up to its elastic limits of 20 tons per square inch. Now, it is laid down in engineering, that in no case will metal stand 900 vibrations, if worked up to its elastic limits, or $\frac{1}{2}$ its breaking strain; but, if worked up to $\frac{1}{3}$ of its breaking strain, 10,000, or even 100,000 vibrations will produce no visible bad effects. A wrought iron tube reduces the diameter of the bore nearly $\frac{1}{3}$, without affecting the useful employment of the steel behind it, and the possible effect might be that it would give the necessary safe margin within the elastic limits, and thus produce a beneficial effect out of all proportion to the reduction of strain which it would cause. Taken in connection with the new gunpowder, it might therefore increase the endurance even of very heavy guns from 1,600 or 2,000 rounds to 10,000 or even 100,000, if the bore were renewed so as not to wear out.

These good results are owing to the great elasticity of wrought-iron which, if used for the bore, not only allows a greater thickness of steel to be employed advantageously behind it, and, as a consequence, greater initial tension, but also brings into play twice the extra tension beyond the initial tension. There seems to be nothing to prevent this plan being carried out with heavy guns, if my system of construction were adopted, for a hard surface would not be necessary with lead coating, and the absence of longitudinal strain would make the welds safe. My gun might thus be made a Palliser gun of enormous strength, and the amount of steel which it is possible to employ usefully would almost make it a Whitworth gun, while the coils, wrought-iron, and initial tension, make it essentially an Armstrong gun. It is a Fraser gun, too, with a thick outer coil, where a

Fig. 16.

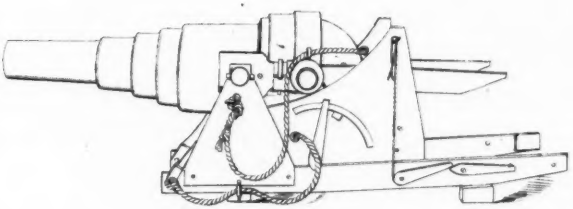
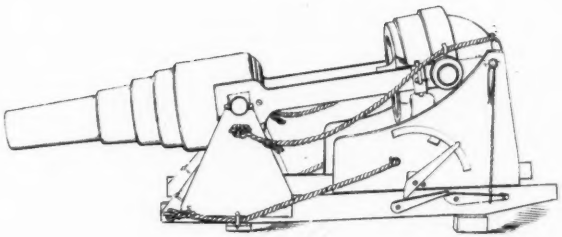


Fig. 17



Scale 1/0

J Jobbins

thick coil ought, and ought only, to be. The only novelty I claim is the new principle whereby it is possible to reconcile all these great authorities.*

Construction.

I have dwelt at some length on these principles, because it is on them that I depend for the success of my gun. The mechanical details are merely the means of carrying them out, and may possibly have to be modified. They seem very simple and natural when embodied in this model, with which I was furnished by the kindness of Sir Wm. Armstrong and Company, while employed at their works at Elswick. It took me fourteen years, however, to arrive at this result. What puzzled me most was to provide for the elevation. I first thought of having a joint between the plug which closes the breech and the weight which absorbs the blow, but that would soon have been smashed to atoms. The next idea was to butt the plug against a dead weight, but, from the varying elevation the force would not have acted through the centre of gravity, which is a necessity with such an enormous pressure. The present idea is to make the plug and weight in one piece, and let it slide along bars which are rigidly attached to the sides of the gun.

When loaded, the gun is balanced on the trunnions with only a slight preponderance sufficient to cause the breech always to rest on its carriage. Elevation or depression is given by running the breech carriage backwards or forwards.

When the gun is fired, the shot and breech move in opposite directions, with velocities inversely as their weights. The shot will thus have left the bore long before the breech is opened. The method of preventing any escape of gas at the breech is shown in Fig. 15, where a steel disc fits on to the front of the plug, and has a paper wad in front of it. This will become tightly jammed so long as the pressure of gas acts on it, and will afterwards be withdrawn by the momentum of the breech.† The breech-carriage also recoils, and this, together with some play between the breech and the bottom of the guide bars, prevents any alteration of elevation during the instant of firing.

The weight of the breech is kept as small as possible, and this no doubt will have the effect of reducing the amount of pressure of gas on the shot; but it will only be to a very slight extent. I have taken the breech as fifty-six times the weight of the shot, so that the pressure would be about 1 per cent. less than in ordinary guns, which are about 112 times the weight of the shot. The initial velocity of recoil will thus be twice that of an ordinary gun, and this would require four times the amount of resistance to pull it up in the same space. Twice

* No doubt these advantages might be combined in any breech-loader which had a wrought-iron barrel and steel breech-piece, but not so effectually as in this gun. I may, however, claim the combination independently of my system of breech-loading.

† Or the wad might remain in the bore after the pressure had ceased, to prevent any escape of smoke, and could be withdrawn at leisure.

the resistance, however, would pull it up in double the space. And I propose doing it in this manner, so as to give sufficient room for loading. There are two sets of compressor bars which act on the breech, one on each side immediately inside the guide bars. There would, besides, be compression between the breech carriage and slide, so as to pull up the carriage when it had recoiled to a suitable distance. The construction of the carriage would also bring the action of gravity to bear at the most suitable moment to produce the same effect. Breech ropes are added for greater security. It may be supposed that this double strain would be apt to injure the pivots with a very heavy gun; but it will be seen that this is not likely to happen, when it is considered that what injures the pivots is not the compressors, but the friction which is brought to play between the carriage and slide during the impact of discharge. In an ordinary gun, the whole weight of the gun rests on the carriage, but in the case of this gun it does not, so that the carriage can more readily slip away.

When the breech-piece is back, the gun is loaded at the breech. The compressors are then released, but not before the breech has been secured to its carriage, in the position it may then occupy, by chains, or some other contrivance. This prevents the breech from descending, and is useful, because the higher the breech, the more readily will it run forward. For if the guide bars are above the horizontal, they tend to help the breech forward; but if below, they tend to retard it in running forward. Should the breech accidentally get low on its carriage, it would have to be run up the bars by means of the running-out-and-in gear. Wheels would be brought into play between the breech and guide bars, and between the breech carriage and slide, but they are not shown in the model, as their action is well known in the working of heavy guns.

This breech action is very simple, and suited to very heavy guns, where great weights must necessarily be moved. The explosion opens the breech, and alters the position of the gun from that shewn in Fig. 16 to that shown in Fig. 17. Gravity brings it back again to its original position.

A much smaller breech carriage can be used, which provides for only sufficient motion of the breech to allow of elevation and depression, but the large one has the advantage of causing the muzzle to dip after firing. This dipping would be useful in allowing the muzzle to hide itself behind a shield or counterscarp, where it would remain sheltered during loading and running up, and need only be exposed at the instant of firing. Another shield or turret could be placed about the position of the trunnions, so as to protect the most vulnerable parts in rear.

The model is designed for a 15-inch gun, and with some alterations, for greater convenience, and to suit the new powder, it represents a very powerful gun firing 200 lbs. of powder, and a projectile of 1,200 lbs. The body of the gun could be made wholly of coiled iron, with the usual steel tube; or, if the suggestions I have made could be carried out, it might have a wrought-iron coiled barrel, and a second course, or a second and third course of steel, in the region of the powder-

chamber. It would weigh about forty tons. The breech would be almost wholly of cast-iron, with a wrought-iron hoop to support the trunnions and the plug of steel, and would weigh about thirty tons. The total weight of the gun would, therefore, be seventy tons, and this is about one-sixth heavier than the proportion of gun to shot, if we consider the present service guns of smaller calibre; but it would probably not be more than the proportion which would be necessary if the present patterns were extended to such a heavy gun. At all events, any excess of weight would be more than counter-balanced by its being divided into two, and by having so large a proportion of the material of cast-iron. I am doubtful, however, if a gun of this size could be made to stand on any of the present patterns, and it is for this reason I have chosen this particular size, though it is impossible to say to what extent the modification of the pressure of gunpowder may extend the limits to which any pattern of gun may be carried. But if, on any of the present systems, a 15-inch gun can be made, I am confident that, on this system of mine, a 20-inch gun might be obtained, firing a one-ton shot, with a breech-piece and barrel of fifty-tons each. If Mr. Reed makes ships carrying 15- and 20-inch armour, both guns will be needed, for it will require 15- and 20-inch guns to pierce them.

Mr. Lacon being obliged to leave during the course of reading the paper, the chair was taken by Sir WILLIAM CODRINGTON.

The CHAIRMAN: Whatever may be thought of the abstruse question of the manufacture of the ordnance of the present day, there is no doubt that the subject is a most important one, both as regards large guns for the Navy and for our fortifications. I am sure, therefore, that the lecture must have been highly interesting to many gentlemen I see around me; and if there are any observations to be made, or any questions to be asked, I hope gentlemen will be kind enough to come forward. I was not here at the beginning of your lecture, but I suppose Captain Morgan that your system is adapted for sea-going purposes as well as for fortresses.

Captain MORGAN: I think it could be adapted, but I have not entered into that question, as I found the branch of the subject almost too long for a single paper, but I trust to have an opportunity of going into that question on another occasion.

Captain BURGESS: There are two questions which Captain Duncan, of the West Cork Artillery Militia, wished me to ask, as, in consequence of a severe accident, he cannot be here to-night. They are as follows: "On what does Captain Morgan specially insist, supposing his system of breech-loading not entertained; would he still prefer breech-loading to muzzle-loading for very heavy guns, and if so, what are his reasons? Are they merely for the sake of convenience in working the gun, or are there advantages as regards manufacture and endurance with breech-loaders over muzzle-loaders?"

Captain R. A. E. SCOTT, R.N.: I should have preferred that some of the gentlemen I see present, who have gone more especially into the details of the construction of heavy guns than I have, should come forward. It is extremely difficult to follow a lecturer through a subject which really requires a great deal of consideration, and upon which an opinion can scarcely be pronounced off-hand. There are many other conditions, it seems to me, besides those which Captain Morgan has stated to us, respecting initial tension; but without going into this question, there are one or two other points that I can speak on. Captain Morgan says that the 12-ton gun burst into fragments in "proof;" and he gives that as a reason for the present manufacture being wrong. I examined the gun carefully, and my own opinion is, that it was not owing to defective manufacture, but that the studs on the shot split it, and then one part of the shot over-riding the other, burst the piece out of the gun. Of course one can only speak from hypothesis, as nothing certain can be known about it, but I did not

see any symptom of splitting in the way that Captain Morgan seems to think the gun did split. I can fully concur, however, in what he says about the heaviest gun, viz., that it is necessary to construct it on scientific principles. There is no doubt about that. There never was a time when careful investigation, joined to practical skill, was more required than at present. We are now pressing for very heavy ordnance, and it seems to me that we are going into the matter without due consideration. I therefore regard this lecture, in which Captain Morgan has called attention to principles of construction, as a very important one; and although I cannot fully concur with his views, nor accept a great many things which he has laid down as axioms, I think there is a great deal in what he says that is valuable, a great deal that requires much consideration, and a great deal upon which I could not offer an opinion, unless I had studied the matter for some months: I allude to the subjects of initial tension and strain, which he has now brought forward. The time, of course, during which the elastic fluid acts upon a given space, has a great deal to do with endurance. I believe guns are often saved from bursting from the pressure being on them a very short time, so that they are very quickly relieved of excessive strain. I also think "mass" has a great deal to do with the strength of guns, as it spreads the shock over a larger area. I do not feel quite sure as to the correctness of Captain Morgan's reasons for the increased strength of the Palliser gun. I think it is very likely that, instead of being strengthened by a portion of the interior being bored out, the gun is weakened; but then the wrought-iron tube which replaces the cast-iron is so much stronger than the cast metal removed, that the gun is greatly strengthened; the removal of the cast-iron is hence of little importance, as compared with the increased strength given by means of the wrought-iron tube. As to the advantages of lead coating, Captain Morgan appears to think they would be very great, but I do not think that lead coating can be got to withstand heavy charges of powder. For even supposing it were made to bear the first pressure of the gunpowder, it would not withstand the high velocity that the shot would get up in passing through the bore. The lead would certainly yield. In a great number of the Armstrong shot fired, there were indications of this yielding of the lead. It was not at the first starting, for the grooves of the gun were thoroughly impressed upon the shot as projections, hence you could see that these projections were pressed round, and did not give the full rotation to the shot at the muzzle of the gun. The Prussians who fire a lead-coated shot, in order to guard against the yielding of the lead and consequent slipping and dropping of the shot in its passage through the bore of the gun, make the grooves smaller and smaller as they approach the muzzle. There is another disadvantage attending the use of lead. Whenever you fire a lead-coated shot there is a great deal of friction, resulting in leading of the rifle grooves as the gun warms. In fact the gun firing leaded shot (bore for bore, and weight of powder for weight of powder) will never give the same velocity that will be given by the gun firing iron shot. I believe that further experiments with lead would produce no satisfactory result. In the 7-inch gun competition of 1864, in which two descriptions of leaded shot were tried, it was found that large portions of the lead were blown off at each round. Now, those portions of lead on the rear of the shot could not be blown off while the shot was passing through the bore; nor do I believe they were even partially detached at first, but are detached as the shot is leaving the bore of the gun. I think all the indications we have had are wholly against the use of lead. The Prussian experience is, I believe, that the shot sometimes go in one direction, and their lead jackets in another. In a sea fight at close quarters, and using leaded shot, instead of hitting your enemy through an opening left in your own line of battle, you might send the lead jacket into a friend supporting you on the one side, and the naked shot into a friend on the other side. In the Newhaven experiments one shot went away half a mile in one direction, and its lead coating went sailing through the air a mile distant in another direction. By-and-bye, an officer from the Coast Guard station came up to say that this lead jacket had knocked down one of the Coast Guard chimneys. Nor was this a solitary instance. A haystack, beside which a man was standing, was hit in the same unexpected way by a lead jacket going to the right, and its shot to the left. In fact you can never depend upon the flight of lead-coated projectiles. Then there is a great difficulty in firing

lead-coated shot from breech-loading guns, which Captain Morgan has mentioned, viz., the difficulty of igniting the time fuze. I think that boring a hole through the shot, as Captain Morgan suggests, would tend to split it. We want the strongest projectiles possible. If our projectiles were stronger, and at the same time were harder at the point, we could make a smaller quantity of powder do the same amount of work, as the present larger charge, and thus relieve our guns. We have gone upon an erroneous principle in making projectiles, and I will be bound to say that if we had to consider the matter at the present time, we should not fall into the same error. We at first adopted solid shot, and now that we are beginning to see the value of shell, we cast the large capacity shell as strong as possible. The next operation is to turn off the outer skin, leaving a porous soft exterior, and not content with having thus weakened the shell—altering the conditions of the atoms of its cast-iron—we then bore a number of holes in it. Not satisfied with this, we next stick in a great number of wedges (studs), and the projectiles thus prepared are issued to the Navy as *common* shell. Now, I think that to those who comprehend the subject, it can be no wonder that the projectiles sometimes break up. The only surprising thing is, that instead of breaking up being the exception, the exception is their keeping together. They break up, however, too frequently to be fired from our turret ships without considerable danger. Not long since I was asked which I considered the most dangerous post on board one of our turret ships? I replied, under the forecastle, and engaged in working the two guns that are supposed to be protected, the bow being covered by armour, as a defence against the enemy's fire; but the crews of these guns would never be safe from fragments of their own turret shot. Recently at sea, shot from the turret guns were fired over the whole length of the deck, but happily the shot did not break up, but afterwards, in firing a-beam, they did break up. If this had happened when firing over the deck, the damage might have been serious. We want a perfectly strong and reliable projectile for the Navy. We already have a strong gun, and I think we may even assert that we have a very strong gun, especially if slow-burning powder be used. The slow-burning powder removes the great difficulty of the excessive strain on the gun at the first moment of ignition of the charge. So that in reality what we now want is, not a safe gun, but a safe shot, and to obtain a safe shot we must have a projectile that is free from the objections I have pointed out. We must not stop here, for we have gone to the limit at which the powder charge of a shell will act efficiently. The small charge of powder which we put into chilled shells at the present time, is not of the slightest use against armour plates. Instead therefore of this inefficient powder, we want gun-cotton, or a still more violently explosive material, to put into shells. Recent experiments tend to show that charges of slow-burning powder will materially assist us in safely using gun-cotton in shells, because the shell will be started more easily; and if it be not checked in the bore, there will be no danger of explosion, but if it be checked in the bore, there will be great danger of explosion. How are we to avoid this danger? By giving up the gaining-twist, and adopting an even twist of rifling. In the gaining-twist, there is a certain amount of jar on the projectiles coming fairly into bearing upon the groove, and there is a still greater jar in the front studs, striking against the driving side of the rifling when near the muzzle of the gun. These dangers are avoided in the *even* twist, and if an iron flanged projectile be likewise used, we should have the necessary conditions for *safety* in firing heavy naval guns. If you have a slow-burning powder you can start the shot easily, and the gaining twist will not be needed; in fact, the danger would be, not in starting the shot, but that the shot would break up, owing to the increasing velocity of rotation as it neared the muzzle of the gun. We must, without doubt, go into a new system of rifling and projectiles for our powerful new guns. I am very glad that Captain Morgan has brought forward the question of heavy guns, for it is one that really deserves a great deal of consideration. He is not the only officer who has thought that breech-loading is very desirable for such guns. Captain Coles is of the same opinion, and he likewise believes that a breech-loading gun can be obtained, and that a large breech-loading gun will make the turret armament perfect. I think Captain Morgan's labours are most valuable; but I am not prepared to say that the plan of gun which he has brought forward is the best, nor is

it probable that it is the plan which Captain Morgan will eventually adopt. Still, he is working in a direction in which investigation is much needed. I am afraid, however, that in the turret, the escape of gas from the breech of the gun will be the great difficulty. It seems to me to be the objection to all breech-loaders, and any escape of gas will cause injury to the men. We had recently an instance in which a great many men were injured by the escape of gas from one of the breech-loading guns. It should be remembered that we commenced with breech-loading guns, and have already given up breech-loading for heavy guns; and now breech-loading is talked of as not being desirable for small guns. Therefore, Captain Morgan will find a great deal of difficulty in fighting his way back to breech-loading, especially as nearly all our experience is against its adoption. I must say, on the other hand, that I do not think any of the experiments which have been made are conclusive. We have attempted to make certain systems of breech-loading answer, instead of first trying to find out which is the best system of breech-loading. These investigations of Captain Morgan will greatly assist us towards the desired end of a final decision upon the merits of breech-loading as compared with muzzle-loading. There is only one other point that I will touch upon, and that is the question of our present varieties of projectiles for the Navy. First, we have the double shell in order to get a large capacity. Everybody acknowledges what an advantage it is to have a projectile of large powder capacity. For the 7-inch gun alone we have double shells, and the experience with these is that they turn over at very short distances. Therefore, if the enemy should be beyond that distance, instead of the shot striking end-on, it will strike on its flat. Another disadvantage attending the use of these long shells is, that one cannot tell where they will glance off to after striking the water, and hence you may strike your friend instead of your enemy. So imminent is this danger, that if I were to be engaged in a general naval action, I should beg my friends not to fire any double shells. We have, secondly, chilled shot; thirdly, we have chilled shell; and fourthly, we have common shell. If a gun were loaded with either of these descriptions of projectiles, the round would not be of any value for the service for which the other descriptions of projectiles were designed. What we want therefore in lieu of all these varieties is, one description of shell that should be good for all purposes. It should pierce the side of an ironclad; it should go through and destroy a wooden ship; and it should fly with certainty of not breaking up in supporting a boat attack; in fact, it should be capable of being fired under all conditions, with perfect safety to the gun, gunners, and friends, and yet be most destructive to the enemy. That is the projectile we should aim at possessing, and I have no doubt we shall eventually get it. The essential conditions for obtaining such a projectile are, first, giving up the gaining twist; and secondly, having an iron shot with projections or ribs, running in the rifling, as upon rails, and keeping the body of the projectile clear of the bore, so as never to strike against it on passing out of the gun. I again repeat, we want a strong projectile, holding a large charge, not of powder, for I think the time for powder is past, but a charge of a much more explosive substance. Shot are useless. They do comparatively little damage, for they only make a hole that can be plugged. If Captain Morgan can aid in obtaining a powerful and destructive projectile, he will deserve the thanks of the Navy; and I certainly think he now deserves our thanks for bringing forward the important subject of manufacturing very heavy guns upon scientific principles. It is really a most difficult subject, and he has treated it in a plain manner, and I, in common with many present, feel very much gratified at having listened to his paper.

Captain BURGESS: I should like to ask another question. I believe the Americans have 15-inch guns; perhaps Captain Morgan can tell us how they are constructed, and whether they are found satisfactory?

Captain SCOTT: May I say one other word. I intended to have mentioned in connection with this subject Mr. Mallet's name, a gentleman who first showed us the principle of building up guns, and who has himself built a mortar of extraordinary power. That mortar has not yet been fully tested, but has given very valuable results. I was in hopes of hearing from the designer and maker of that mortar, Mr. Mallet, who has studied the subject of initial tension, and so well worked it out in his

mortar, some remarks upon Captain Morgan's paper. I think the country is very much indebted to Mr. Mallet, and therefore it is just in discussing these questions not to forget those pioneers from whom we have derived a great deal of information. In making these observations, I do not mean in any way to detract from the merits of Sir William Armstrong, who has done so much for us. He deserves so well of the nation, and his services are so well known, that any praise of mine would be out of place.

Mr. RIGG: As Captain Morgan has been kind enough to mention my name with reference to his heavy breech-loading gun, perhaps I may be permitted to make one or two remarks. I quite agree with him that the difficulties of the question are both theoretical and practical. On the practical question I may mention my having a few years ago made many comparisons of guns used in various countries, especially those that had been employed in the American war; and from these observations, the principles which Captain Morgan has advocated this evening seem to be correct. I examined a number of guns which burst at Charlestown and other places, and noticed a remarkable fact, namely, that those which lasted longest had invariably the heaviest breech. One gun in particular to which Captain Morgan has referred, stood 4,606 rounds, whereas the general run of them burst at about two or three hundred rounds. That remarkable specimen of endurance was a Parrott gun, like the model on the table; and the wrought-iron reinforce had been accidentally shrunk on to the breech, instead of as is usually the case, upon the barrel. The proportion of weight between the breech, as it usually blew out, and the gun was about 1 to 10; while in this particular instance it was about 1 to 2¼. The usual proportionate weight of the shot to the breech is 1 to 18·5; of the shot to the barrel 1 to 186. Now, comparing the initial velocity of the shot, ascertained with some of these guns to be 1,436 feet per second, with the masses of breech and barrel respectively, the velocity of the former would be 77·5 feet per second, if free to move; whereas the velocity of the barrel would be 7·75, a difference of 69·75 feet, which represents the longitudinal strain upon the gun. Now, the gun which burst at Charlestown, after firing 4,606 rounds, being made accidentally, on the principles which Captain Morgan advocates, had a proportion of shot to breech as 1 to 46, and of shot to barrel as 1 to 103·5. Compared with the velocity of shot (1,436 feet per second), the velocity of breech would be 31·1 feet; the velocity of the barrel 13·8 feet; giving a difference of 17·3 feet, representing the longitudinal strain, instead of, as in the other case, of 69·7; thereby showing that the increased weight of the breech compared with rest of the gun, had a remarkably beneficial influence upon its endurance, and enabling it to fire more than ten times the average number of rounds. With reference to the remarks of Captain Scott on gas escaping from the breech of Captain Morgan's proposed gun, it seems worth observation that the usual breech-loading guns have a most miserable fastening for the breech-piece. Not only is the strength cut away where it enters, but what exists is very insufficient. That small section of iron having to sustain the enormous impact of the shot (for the discharge of a shot from a gun is like the blow of a hammer on the base of the bore) must of necessity yield a trifle, and so let gas escape when at its highest pressure. Captain Morgan's model shows his breech-piece to travel 18 inches before opening, and this allows ample time for the shot to be discharged and the pressure reduced, so that whatever gas does escape, will be cool and infinitely less in quantity than with any other breech-loading gun, and there can be no difficulty in getting rid of it.

The paper which Captain Morgan has read, and his diagrams, render the principles he advocates very clear, and I may be permitted to add that his gun coincides more closely with those which have hitherto shown the highest endurance than any other proposal. Its general principles seem sound, and I think that when fairly carried out, it promises to be a most admirable breech-loading gun.

Mr. MALLET, C.E., F.R.S.: I did not intend to say anything, I came here to learn, and I have been instructed by the admirable lecture we have heard. I do not know that I have ever heard the fundamental principles of ringed construction in guns more lucidly explained. Some deductions which Captain Morgan has made, I perhaps, should not quite be prepared to coincide with. But the subject, as has been remarked by Captain Scott, is so large and multifarious, that it would take four or five even-

ings to discuss it fully, and in the order of its various heads. I would make but one remark. If I understand the views of Captain Morgan, in the large gun, which he proposes to make in such a form as to take up the resistance of the breech to the propulsion of the shot by inertia, instead of by a longitudinal strain on the chase of the gun itself, it is rather as an incidental result of his method than as intentionally and primarily a breech-loading gun, that the inventor presents breech-loading as one of its advantages. Captain Morgan's gun has, as a consequence of his method, the advantage of being a breech-loading gun. But I should like to understand whether Captain Morgan is prepared to espouse as a generally advantageous principle, breech-loading for all very heavy guns. For my own part, the result of my observations at home, in France, and in Prussia, is to suppose that the days of heavy breech-loaders are drawing to a close. The mechanical difficulties involved in them, in every form that I have seen as yet, appear to me practically insuperable. I do not say that they have not some advantages. Were, however, this method of Captain Morgan found to be practicable upon a large scale, breech-loading would be unquestionably obtained, as a consequence, without any of the disadvantages that at present belong to it in other forms. In order to obtain a breech-loading gun, you must so cut the gun to pieces, by forming a large hole on two opposite sides of the chase, that the direct strains, both longitudinal and circumferential, where you so cut it, are enormously intensified, but the jar through the gun at the moment of discharge (which is a perfectly symmetrical pulse wave in both the longitudinal and circumferential directions in a muzzle-loading gun) becomes unsymmetrical in a breech-loading gun, and thus the tendency to cause the parts to fly asunder at the place of sudden change of section is very great indeed. Now this evil, incidental to all existing breech-loaders, would have no necessary existence in Captain Morgan's gun with the separate breech, in which the strain, as well as the pulse-wave, remain nearly, if not quite, as symmetrical as in the old muzzle-loader. Whatever advantages breech-loading may afford—if any—in very heavy guns, Captain Morgan's construction presents, therefore, without the usual disadvantages. As to this construction itself, I do not venture to offer any opinion, as, however sound in principle, it involves many questions of a practical character that would demand prolonged consideration.

Captain MORGAN: I really feel that the various gentlemen have spoken so well that there is very little to object to in anything they say. In attributing "initial tension" to Sir William Armstrong, I quite forgot Mr. Mallet. I have not very clear ideas to what the nature of his mortar is; only, if he was the first to bring forward "initial tension," I should be very happy to retract what I said of Sir William Armstrong. All I want to enforce is, the great value of "initial tension." You may be aware that some people laugh at it, and think it altogether useless; even great authorities in gunnery, but I do not at all agree with them. Captain Scott said a great many things which I most thoroughly agree with. I think his objection with respect to the escape of gas in this particular breech-loader of mine was taken up, according to my views, by Mr. Rigg. In an ordinary breech-loader there is no length of recoil in the breech-piece that closes the breech; the first motion is a motion of opening. But in this gun of mine the first motion is a jamming motion; then there is a slide-back; so that the greater the pressure, the tighter it is; it does not open it, it tightens it rather. The only thing to have to guard against is this, that after the plug is drawn back, when it is drawn back suddenly, it is difficult to prevent any smoke coming out from the bore. In order to guard against that, I would leave the paper-plug sticking in the bore. Then, Captain Scott spoke about the lead stripping. I think I particularly guarded myself upon that point, and I admitted all these difficulties. But I was very careful to say that if this gun was only tried as an experiment for that particular purpose, it might give us results which would enable us to go on further. I would not advocate lead-coating until we know something more about it. But I think the reduction of the initial pressure of gunpowder has so much altered the question, that any argument we hold with respect to the quick-burning powder would not hold with slow-burning powder. A book has been published by Captain Dopplemair of the Russian Guards. From it I gather that the Prussians seem to have made marvellous progress in the method of fixing the lead-coating; they seem to say that they have got over these difficulties.

I do not admit everything I see printed, but this seems to come on very good authority. All this needs waiting for. For my part I am not inclined to bid lead-coating "good-bye" until further experiments. I think the only question I should make any dispute upon is about that 12-ton gun that burst at proof. Captain Scott seems to think the cause was the shot jamming in the bore. Captain Stoney seems to think it was owing to the weakness of the steel tube. I would say, with regard to shot jamming in the bore, how is it that the other shot referred to by Captain Scott, if they jammed in the bore, did not burst the other gun? The fact is, if the shot jams in the bore and the gun is strong enough, the shot must go, it cannot stick in the bore. But supposing a shot to jam in the bore, if any gas escaped from this gun of mine, it would not hurt the gunners, even if it escaped with great pressure; because I have constructed this breech so that that result would not follow. It would open gradually and the flash would be thrown forward, and naturally the gunners would stand behind; so there would be no danger of accident.

An AUDITOR: Would it open before the shot is out of the gun?

Captain MORGAN: No, it has a recoil of 18 inches, so that the shot would be out of the gun before the breech would move three inches. But I believe if a shot were to stick in the bore, this would act as a safety-valve. Then, with respect to the various shells that Captain Scott referred to, and to the possibility of having one description to do everything. I think that unless you have a very large bore and a very heavy gun, you will never be able to get a shell having a large bursting charge that will pierce armour plates. I think his remarks are very valuable about the length of the shells. I do not at all approve of long shells; it is a totally false principle, because you increase the strain on the metal towards the base. The longer the column is, the greater is the strain on the base; therefore that is the reason why I am in favour of as large a bore as we can get. Increasing the size of the gun I should not go on at this ratio, but I would go on to a larger ratio of bore compared with the weight of the shot. But they seem to be going in the contrary direction at the Arsenal. They are making the new 35-ton gun with a 11½-inch bore. The proper proportion would be a 12½-inch bore; a 12-inch bore is the proper bore for a 600-lb. shot. This gun of mine is the same proportion as the 9-inch gun, that is to say, 15-inch bore for a 1,200-pounder. I do not believe you can get the proportionate strength with small calibres. They are going on to two calibres with a steel tube. I hold that part of the strength is wasted. You increase the strain on the bore, without increasing the strength of the gun in proportion. Two calibres thickness may be used with a wrought-iron tube inside a steel one, but only 1½ calibres if the inside be of steel. I feel very much indebted to those gentlemen who have spoken, for the manner in which they have taken up the subject.

Captain BURGESS: I asked a question about the 15-inch American gun; I believe they have a 20-inch gun also.

Captain MORGAN: I think so. Their guns are made of solid cast-iron, and I think they have also made some with a wrought-iron tube outside. That was the first principle that was proposed by Sir William Armstrong. He was asked how he could strengthen the cast-iron guns. But it is found very much inferior to Major Palliser's plan. The Americans go on the principle of a large bore and a round shot. With respect to a point whether this particular plan of breech-loading should be adopted, I may say there are two distinct questions involved in this. There is this particular form of breech-loading which will increase the strength of any gun you choose to apply it to; that is to say, if we take an old cast-iron gun and adopt this form of breech-loading, you will make that gun very much stronger on the principles mentioned by Mr. Rigg. You will have no cross strain in the bore, and you will not only relieve the gun of one chance of bursting, but you will also diminish the other. Then, if you apply it to an Armstrong gun like this, or to a Fraser gun, it will make that very much stronger. Any gun will be made stronger. But, then, I claim also the wrought-iron tube, not that exactly, for Major Palliser has the first claim to that; but I claim a combination of Palliser, Whitworth, Armstrong, and Fraser. I claim the combination of these: the initial tension, which is well known; then I begin with a Whitworth gun, and I put two layers of steel here; then here is the Palliser tube inside; then there is thick Fraser coil outside.

I claim that to be the best combination for giving strength to the tube, as you see by those curves and those diagrams on the wall. Then this plan, although best combined with this form of gun, can be combined with any other form of breech-loader. But if you had another form of breech-loader you could not have these short coils, you could not have these coils rolled out like tyres of railway wheels. But if we were to dispense with this form of breech-loading for another, then all you have to do would be to make a steel breech up here, and then screw another steel coil on here in front; the same conditions would hold for any other breech-loader. Now comes the question, why do I prefer the breech-loader to a muzzle-loader? That is really the point in dispute between myself and Captain Scott. I feel all the difficulties just as much as anyone can; and if he can show me any plan in which you can have strength equal to a wrought-iron tube inside, then I shall be happy to adopt that plan. But if I increase the strength of my gun one-half, and if by increasing the strength thus, I can increase the endurance of my gun from 1,000 or 2,000 to 10,000 or 100,000 rounds, I think that is a gain not to be thrown away. I admit that a wrought-iron tube cannot stand the strain of the studs which Captain Scott has referred to. If it were possible to have a muzzle-loading gun that will stand the action of the studs, then let us have a steel breech-piece here and wrought iron outside.

Captain SCOTT: I said that you get a great deal of escape of gas between the studs; that is what causes the erosion of the bore.

Captain MORGAN: Could we have that rib working in a wrought-iron bore?

Captain SCOTT: Perfectly.

Captain MORGAN: Then you and I quite agree. I should be happy to have a gun made on that principle. I only wish to have a wrought-iron tube; I think that is essential for strength.

Captain SCOTT: Although it is against the rule to speak again, I should like to be permitted to make one more remark. The experiments which have lately taken place in the Arsenal have shown that a dissimilar friction takes place. The earlier experiments showed that lead rubbed down the bore much more than iron shot. With Bashley Britten's gun, after 200 rounds, it was found that the lead had worn away the edges of the groove. But if you have wrought-iron rubbing against cast-iron, the friction is scarcely anything. My gun fired 400 rounds. The plug was taken out at the conclusion of the firing; the gauge was applied, and it perfectly filled the bore; the bore was not expanded in the least, the erosion was almost *nil*. On the other hand, with a stud shot, the rifling was very much worn down. Where the stud had rested, there was a considerable indentation, and the bore was expanded very considerably. The whole of the results which we have, and which are not generally known, I am throwing together with the view, if I am permitted next year, of bringing the question of guns—because it is a most important question—before the members of this Institution at the commencement of the session, when this question will be fully discussed, and more fully discussed than it can be at the present time.

Captain MORGAN: I do not think that I have any other questions to answer. I feel there are many difficulties on both sides. It is a question for mature consideration and for experiments, and if we could have these experiments carried out, we might learn something from them. With respect to wrought-iron bores, we have no wrought-iron bores in our service; with our heavy guns we have all steel tubes. I quote from Sir William Armstrong; he says, "With these experiences before me, it is impossible that I can hold any other opinion than that the vibratory action attending excessive concussion, is more dangerous to steel than to iron, and were it not necessary to provide a harder and more homogeneous substance than wrought-iron for the surface of the bore, I should entirely discard steel from the manufacture of ordnance." That is the view I take of the question; but, of course, one authority is not competent to decide that point. My views are, that if we could have a wrought-iron tube, it would so materially increase the strength of the gun, that we ought to take any means to get it. The only thing I thought was that, with a softer metal, like lead, there would be less rubbing away of the bore. But if lead rubs more, as Captain Scott says it does, of course, if it is contrary to experiment, it is a different

thing altogether. One advantage is this, that lead would stop the windage. There is no doubt that a lead-coated projectile will stop the windage, and so prevent that guttering of the iron which wears out the bores of the guns in our service.

The CHAIRMAN: We return our thanks to Captain Morgan for his very valuable paper. The more a question of this sort is gone into, the more it becomes a question of practice and experiment, and were the results communicated to us, the better would it be for the Services.

MACHINE GUNS: THE "GATLING BATTERY"—THE AGAR AND CLAXTON GUNS—THE FRENCH AND MONTIGNY MITRAILLEURS.

By R. J. Gatling, Inventor of the "Gatling Battery."

Though inventors at this day need not fear the violence that drove Foudrinier from France, and the inventor of the stocking-loom from England; and though they may have free access to the public ear, yet it by no means follows that the road to success is smooth and easy. Men, and especially Governments, are still slow to adopt plans and designs at variance with their old-established notions. There seems to be an innate feeling in human nature to "bear the ills we have," when the way to escape them lies through a new invention. Besides, the cost of patenting, introducing, and thoroughly testing an invention is very great, while those interested in established businesses—in many cases very large—never fail to use their powers to crush it, if it seems likely to supersede their old processes and purposes.

It will thus be apparent that all inventors, even at the present time, have difficulties to encounter in the accomplishment of their object; especially, I apprehend, is this true in the Military Departments of Governments.

As before remarked, Governments are slow to adopt improvements, even slower than individuals. It was only after a most strenuous effort that the old match lock was forced to give way to the flint lock, and this held its own for many years, against all efforts to supersede it with the percussion lock. It is a notorious fact that the rifle barrel was in use among sportsmen for very many years, before it was adopted by any Government. The inventors of breech-loaders will readily recall the many disappointments and rebuffs they met with from European Governments until the Prussians adopted them, and demonstrated their great superiority upon the battle field of Königgrätz. It is evident that their advantages over the Austrian Army were won by the use of the needle-gun. Then, for the first time, the other European Governments saw the effectiveness of the breech-loader, and made haste to adopt it.

The great expense consequent upon the new armament of an army, the change of tactics compelled by the new order of things, and the vast amount of money invested in the manufactory of arms in use, form a barrier, high and strong, against all attempts to introduce new

arms, however safe, efficient and cheap they can be demonstrated to be.

Yet, despite these impediments, it is a matter of congratulation that useful inventions, sooner or later, find their way to public approval and adoption. This consideration has encouraged me to persevere in the laborious and expensive efforts to which I have devoted nine years of my life to invent an improved gun, on a new and correct principle, to take the place, or to act as auxiliary to those now in general use. This weapon, generally known as the "Gatling gun," or "battery," has been brought to the notice of the American and European Governments for several years past, and its efficiency tested. Many trials have been had; and by these practical, and after all only true and convincing tests of its operations, made and to be made, I was willing to abide. But it seems that the inventors of other and rival arms are not content to be judged by the results of such trials, and have availed themselves of the powerful auxiliaries of able pens and printer's ink to extol their own, and decry and unfairly criticise my invention.

While I believe that no useful invention can be written down, or a faulty one written up, permanently, yet I am free to confess that "the worse may be made to appear the better argument," and silence on my part might be considered as an acknowledgment of inability to answer the objections urged against my weapon. This must be my excuse for asking a few pages in the influential Journal of the Royal United Service Institution to lay before its members and the public, in as brief a manner as the importance of the subject will permit, the history and description of the "Gatling battery," and a rebuttal of the objections urged against it, particularly by Major G. V. Fosbery, in an article headed, "On Mitrailleurs, and their Place in the Wars of the Future," published in No. LVI, volume 13 of that Journal. This article only reached me through the kindness of a friend, a few weeks ago, which will account for its not receiving earlier notice.

History of the Gatling Battery.

A man is entitled to the fruits of his labour, and to assert a just claim is a duty as well as a right. In the year 1861, I first conceived the idea of a machine gun, which has been ever since the great controlling idea of my life; and it certainly cannot be regarded as egotism when I express the belief that I am the originator of the first successful weapon of the kind ever invented. A brief history of this arm may establish the fact, and cannot fail to engage the attention of all who take an interest in fire-arms.

I completed my first "battery," or "machine gun," in the city of Indianapolis, State of Indiana, my place of residence, in the early part of the year 1862, and my first American patent bears date November 4th, of the same year. The gun was fired repeatedly during that year, in Indianapolis, in the presence of hundreds and thousands of persons, over two hundred times a minute, and the result published to the world.

In the autumn of 1862, I went to the city of Cincinnati, in the State of Ohio, and in the well-known establishment of Miles H. Greenwood and Co., I had six of my guns constructed; but about the time they were completed the establishment was destroyed by fire, together with the guns, patterns, and drawings, subjecting me to a heavy pecuniary loss. Shortly afterwards, I had twelve of my batteries manufactured at another establishment in the same city. In the meantime, I continued to fire my gun, made at Indianapolis, before the citizens of Cincinnati, and in the presence of many Army Officers of rank and distinction, all of whom were highly pleased at the result of its performance. The American press of 1862 and 1863 teemed with accounts of these trials, and during all this period no notice of a similar weapon, at least none equalling or approaching the "Gatling battery," in the rapidity of its firing, appeared in any of the papers published in America or Europe.

I made no effort to keep my invention a secret, but, on the contrary, published full descriptions of the gun, with cut and diagrams, and sent the same to all parts of the civilized world. I stated in these descriptions that my invention consisted of a gun formed of a "series of barrels," parallel to each other, arranged around a central shaft, and that "each of the barrels was furnished with its own appropriate lock, or firing mechanism;" I also described it as a "compound machine gun," that is, many guns in one. At the time I made these publications, that "mysterious" French mitrailleur, of which we have since heard so much, was not invented, and, in my opinion, not even thought of. It is well known that the French and Montigny mitrailleurs are composed of a number of barrels, and have a lock or firing device for each barrel, and, for reasons submitted hereafter, I have no hesitation in saying, that this feature of a gun, formed of many barrels and many locks, is copied from my invention.

I continued to make my guns in Cincinnati during the years 1863 and 1864, and in the autumn of the latter year, I made additional improvements to my battery—in the locks and rear cam—but without, however, changing its main features, for which I secured a second patent of the United States, bearing date May 9th, 1865.

In the years 1865 and 1866, these improved guns were manufactured at Cooper's Fire Arms Manufactory, in the city of Philadelphia, but since that time they have been constructed in large numbers, at Colt's Armoury, in the city of Hartford, where machinery has been fitted up at great expense, to build the guns in the highest style of perfection.

As heretofore stated, I made my first gun in Indianapolis, in the early part of the year 1862. Governor Morton, then Governor of the State of Indiana, and now a Senator in the Senate of the United States, being favourably impressed with the invention, appointed a committee of gentlemen of high standing and military experience, to examine and report upon its merits. The following is a copy of their report:—

"To His Excellency
"Gov. O. P. Morton,
"Sir,—The undersigned, agreeably to your request, have examined with much care the revolving gun of Dr. Gatling.

"They have also witnessed several trials of it, both with blank and ball cartridges.

"We are aware that nothing but actual service in the field, subject to all the casualties of war, can fully establish the utility of any arm, but in this gun, as far as we have been able to judge, everything has been anticipated to render it effective under all circumstances.

"The lock is certainly ingenious and simple in its construction, and fully protected from injury from any cause. The barrels are so arranged as to fire independently of each other, so that an injury to one does not affect the others. There are no complicated parts, and the common soldier can keep it in order as readily as he can his musket. It is so substantial as to endure without injury the same usage as an ordinary field-piece. The discharge can be made with all desirable accuracy as rapidly as 150 times per minute, and may be continued for hours without danger, as we think, from overheating. Two men are sufficient to work the gun, and two horses can carry it over the field with the rapidity of cavalry. The very low price at which the gun can be made, its superiority in every respect, induce us to hope that your Excellency will order enough to be immediately constructed for a fair experiment in the field.

"We are, very respectfully,
"Your obedient servants,
(Signed) "T. A. MORRIS.
"A. BALLWEG.
"D. G. ROSE.

"Indianapolis, July 14th, 1862."

The date of this report, July 14th, 1862, establishes my statement in reference to the manufacture and firing of my first gun, in the early part of 1862 And in this connection I will further state that one of my battery guns, made in 1862, and bearing that date, can be found in the Ordnance Museum, at Washington City.

The result of this trial was so satisfactory as to impress Governor Morton with the desire to have the gun introduced into the service of the United States, as the following letter from His Excellency to the Assistant Secretary of War will show:—

"State of Indiana,
"Executive Department,
"Indianapolis, Dec. 2nd, 1862.

"Sir,—Allow me to call your attention to the 'Gatling gun,' invented by Dr. R. J. Gatling, of this city. I have been present at several trials of this gun, and without considering myself competent to judge certainly of its merits, am of the opinion that it is a valuable and useful arm. Dr. Gatling desires to bring it to the notice of your Department, with the view of having it introduced into the Service.

"I cheerfully recommend him to you as a gentleman of character and attainments, and worthy in all respects of your kind consideration. Any favour you may be pleased to show him will be duly appreciated.

"Very respectfully,
"Your obedient servant,
"O. P. MORTON,
"Governor of Indiana.

"P. H. Watson, Esq.,
"Assistant Secretary of War,
"Washington, D.C."

The following letter from Major-General H. G. Wright, then in command of the United States forces at Cincinnati, where he saw the gun repeatedly fired, to General Ripley, the then Acting Chief of the Ordnance Department at Washington, gives the opinion of another

experienced Officer who had ample opportunities to judge of the efficiency of my battery:—

"Head-quarters, Department of the Ohio,
"Cincinnati, March 11th, 1863.

"Brigadier-General J. W. Ripley,
Chief of Ordnance, U.S.A.,
"Washington, D.C.

"General,—I have examined, in company with Lieutenant Edson, Chief Ordnance Officer of this Department, the invention known as the 'Gatling gun,' and it seems to me to possess much merit.

"As a device for obtaining a heavy fire of small arms with very few men, it seems to me admirably adapted to transport steamers plying upon the Western rivers, where infantry squads are needed for security, against guerilla and other predatory bands.

"Mr. Rindge, the agent for the gun, visits Washington, and I would ask for him the opportunity to exhibit the invention to you, or some designated Officer of your Department.

"Very respectfully,
"Your obedient servant,
"H. G. WRIGHT.
"Major-General Commanding."

Several trials of one of my guns took place at the Washington Navy Yard, in the months of May and July, 1863, and the following extracts are taken from the official reports:—

"Navy Ordnance Yard,
"Washington City, May 20th, 1863.

"Rear-Admiral John A. Dahlgreen,
"Chief of Bureau of Ordnance.

"Sir,—In relation to the 'Gatling gun or battery,' I have to report as follows:—

"The gun consists of six rifle barrels, of $\frac{58}{100}$ inch calibre; each barrel is firmly connected to a breech-piece by a screw of 1 inch in length. The breech-piece is composed of one solid piece, which is made secure to a shaft $1\frac{3}{8}$-inch in diameter. The barrels are inserted in the breech-piece around the shaft, on a parallel line with the axes of said shaft, and held in the proper position by a muzzle-piece, bored by the same guage as the holes for the breech-piece for the reception of the barrels. The breech-piece is also bored in the rear end, for the reception of the locks, on a parallel line with the barrels, each barrel having its own independent lock, revolving simultaneously, so that in case one lock or barrel becomes disabled, those remaining can be used effectively.

"Between the locks and barrels is a receptacle for the charges on a parallel line with the locks and barrels. As the entire gun revolves, the charges find their way through a hopper, containing any given number, fed from cases, instantaneously. The breech-piece contains the locks, and is entirely protected by a heavy casing of gun-metal, made fast to a wrought-iron frame, resting on trunnions $1\frac{1}{4}$ inches in diameter. It is screwed to the frame by four bolts. Inside this casing is attached an inclined ring, which the hammers of the locks ride as the gun revolves, until, coming to the point of line of fire, when the discharge takes place. The locks are composed of three pieces and one spiral spring, and are entirely protected from dust or any injury. The gun is mounted as other field-pieces, with limber attached.

The report concludes as follows:—

"The gun or battery has stood the limited test given it admirably; has proved itself to be a very effective arm at short range; is well constructed, and calculated to stand the usage to which it would necessarily be subjected. It is suggested that an improvement in the manner of rifling the barrels would be advantageous.

"Respectfully submitted,
"J. S. SKERRETT.
"Lieut. Commanding, U.S.A."

At the suggestion of Lieut. Skerrett, I had a new set of barrels, with a change in the rifling, made and put in the gun, and it was on the 17th of July, 1863, again fired at the Washington Navy Yard, in the presence of a number of Officers.

The official report of the trial states that "the penetration of the "Gatling battery was equal to that of the Springfield musket;" that the gun in its "mechanical construction is very simple, the workmanship "well executed, and we are of the opinion that it is not liable to get "out of working order."

The trials were so satisfactory to Admiral Dahlgreen, that he gave permission to Commanders of Fleets and squadrons to order what guns they might think proper for the Service; but few guns were furnished, however, owing to my inability to make them in quantities, and want of time to see Naval Officers and impress upon them the value and true character of the gun. Some of them, however, did get into service before the close of the American war, and were used effectively in repelling rebel attacks upon the Union forces, under command of General Butler, near Richmond, Virginia.

I continued to make new experiments and new models, changing the details; and in the latter part of 1864 I made most valuable improvements, chiefly in the lock mechanism and rear-cam. One of these improved guns was sent to Washington, in January, 1865, and was submitted by General John Love to the Ordnance Bureau, and a trial of the gun was at once ordered to be made, which was done at the Washington Arsenal in the same month. The following extracts are taken from the official report of the trials:—

"Total weight of gun, exclusive of carriage, 224 lbs.
" carriage .. .. 202 lbs.
" limber .. .. 200 lbs.

"The advantages claimed for this gun are:—
"1st. There is no escape of gas at the breech.
"2nd. There is no recoil which can destroy its accuracy.
"3rd. It performs the operations of loading, firing, and extracting the case by simply revolving the crank.
"4th. Accuracy.
"5th. Rapidity of fire.
"The gun certainly possesses the advantages of rapidity, accuracy, and loads, fires, &c., while the barrels are revolving.
"There is no escape of gas at the breech; it has one lock for each barrel, so that in the event of one barrel or lock becoming disabled, the gun is still efficient, as the rest of the barrels can be used without difficulty."
The report concludes in the following words:—
"All parts of the gun worked well.

"J. W. MACLAY.
"2nd Lieutenant U.S. Artillery."

The gun used in this trial was $\frac{58}{100}$ inch calibre. General Dyer, Chief of Ordnance, being desirous of the further development of the Gatling system, suggested the construction of guns of 1 inch calibre, and ordered full trials of the same to be made at the Frankfort Arsenal, Philadelphia. In order to conduct these trials successfully, machinery was constructed at the Arsenal expressly for making the large metallic

shells for the 1-inch cartridge. In the meantime, eight of the 1-inch calibre guns were made by the Cooper Fire Arms Manufacturing Company, at Philadelphia, under the superintendence of the inventor. As soon as these arms were completed, they were placed under the charge of Colonel S. V. Benét, the able and accomplished Ordnance Officer, in command of the Arsenal, by whom prolonged series of trials were made.

Colonel Benét's report of these trials says:—

"The gun worked smoothly in all its parts, and the cartridges were fed and the cases thrown out after firing, with ease and certainty. The cartridge also worked well, and no more difficulty is to be experienced with it than with any other metallic cartridge of similar construction, if indeed so much."

Subsequently to the foregoing trials, three of the guns were taken to Washington, and fired hundreds of times, in the presence of General Grant, now President of the United States, Generals Hancock, Dyer, Maynadier, Hagner, and a great many other distinguished Army Officers and Government officials.

The Chief of Ordnance then ordered one of the guns to be taken to Fort Monroe, Virginia, to be fired, in comparison with the "24-pounder flank defence Howitzer." The following extracts are taken from the official report of this trial:—

"Fort Monroe Arsenal, Virginia,
"July 14th, 1866.

"Major-General A. B. Dyer,
"Chief of Ordnance.

"Sir,—I have the honour to state that in obedience to your letter of May 31st, 1866, I have tested Gatling's rifle gun, in comparison with the 24-pounder flank defence Howitzer, and I have also fired it with ball cartridges at targets.

"The results of the experiments are herewith forwarded.

"I consider it a superior arm to the 24-pounder Howitzer, for flank defence, as from 80 to 100 buck and ball cartridges can easily be fired from it in one minute, being a discharge of from 1,200 to 1,600 projectiles, while from the 24-pounder flank defence Howitzer, only four rounds can be fired in the same time, giving for canister 192 projectiles, and for case shot about 700.

"The moral effect of the Gatling gun would be very great in repelling an assault, as there is not a second of time for the assailants to advance between the discharges.

"The machinery of this gun is simple and strong, and I do not think likely to get out of order. I had the oil rubbed off this gun, drenched it with water, and then exposed it for two nights and a day to the rain and weather, but though it was quite rusty, it was fired 97 times in a minute and a-half, one man turning at the crank.

"In my opinion this arm could be used to advantage in the military service, as a flank defence gun, and mounted on a field carriage, to defend a bridge, causeway, or ford.

"The size of the bore might be increased to advantage, which would allow the buck and ball cartridges to contain a greater number of, and larger sized balls.

"Respectfully your obedient servant,
"T. G. Baylor,
"Captain of Ordnance, and
"Brevet-Colonel U.S.A. Commanding.

"A true copy.
"A. B. Dyer,
"Brevet Major-General, Chief of Ordnance."

After these trials, the United States Government adopted the Gatling

battery gun, and on the 24th of August, 1866, gave an order for 100 of them, 50 of 1-inch calibre, and 50 of $\frac{50}{100}$ inch calibre, which were made at the Colt's Armoury, and delivered in 1867.

In May, 1868, another trial of large and small-sized Gatling guns took place at the United States Navy Yard, at Washington City, and the following is copied from the report of the distinguished Naval Officers who constituted the Board, to test and report upon the merits of the gun :—

"Washington, D.C., May 30, 1868.

"Hon. Gideon Welles,
"Secretary of the Navy,
"Washington, D.C.

"Sir,—The undersigned, composing a Board, appointed by your order of the 14th instant, to examine, test, and report upon the merits of the Gatling gun, as to its value for use in the Navy, have the honour to submit the following report :—

"From the examination made of the gun, and the report of tests hereto appended, the Board is of opinion that, as an auxiliary arm for special service, to be used from top-gallant, forecastle, poop-deck, and tops of vessels of war, and in boat operations against an enemy, either in passing open land works or clearing breaches and other proposed places for landing from boats, &c., if opposing infantry and cavalry, it has no known superior.

"Its great merit consists in its accuracy within the limits of its range; the certainty, and, if need be, rapidity of fire, with the additional merit of only requiring three persons to load, direct, and fire each piece, when suitably mounted, afloat or ashore.

"The following detailed report of the trial will, it is believed, fully sustain the opinion of the Board." (Here follows a detailed report of the trial, and a full description of the gun and its ammunition, which is too extended to be inserted in this paper.)

The report proceeds thus :—

"'The mechanism (of the gun) is simple, and not likely to get out of order ; but in such an event it could be repaired on board ship. Spare pieces, as in musket locks, could be a part of the outfit.'

"The report concludes by saying that at the close of the trial, ten shots were fired at an elevation of 10° 40′, giving by the plane table an average distance of 2,800 yards. None of the cartridges missed fire.

"Very respectfully,
"Your obedient servants,
"M. Smith, Commodore.
"Thornton A. Jenkins, Commodore.
"John L. Davis, Commander.
"K. R. Breese, Commander."

Description of the Gatling Gun.

The following is a brief description, so far as it is possible to describe it without drawings, of the construction of the "Gatling battery."

The gun consists of a series of barrels in combination with a grooved carrier and lock-cylinder. All these several parts are rigidly secured upon a main shaft. There are as many grooves in the carrier, and as many holes in the lock-cylinder as there are barrels. Each barrel is furnished with one lock, so that a gun with ten barrels has ten locks. The locks work in the holes formed in the lock-cylinder on a line with the axis of the barrels. The lock-cylinder, which contains the locks,

is surrounded by a casing which is fastened to a frame, to which trunnions are attached. There is a partition in the casing, through which there is an opening, and into which the main shaft, which carries the lock-cylinder, carrier, and barrels, is journaled. The main shaft is also at its front end journaled in the front part of the frame.

In front of the partition in the casing is placed a cam, provided with spiral surfaces or inclined planes. This cam is rigidly fastened to the casing, and is used to impart a reciprocating motion to the locks when the gun is rotated. There is also in the front part of the casing a cocking-ring, which surrounds the lock-cylinder, is attached to the casing, and has on its rear surface an inclined plane, with an abrupt shoulder. This ring and its projection are used for cocking and firing the gun. This ring, the spiral cam and the locks, make up the loading and firing mechanism.

On the rear end of the main shaft, in the rear of the partition in the casing, is located a gear wheel, which works to a pinion on the crank-shaft. The rear of the casing is closed by the cascable plate. There is hinged to the frame in front of the breech-casing a curved plate, covering partially the grooved carrier, into which is formed a hopper or opening, through which the cartridges are fed to the gun, from feed cases. The frame which supports the gun is mounted upon the carriage used for the transportation of the gun.

The operation of the gun is very simple. One man places a feed-case filled with cartridges into the hopper; another man turns the crank, which, by the agency of the gearing, revolves the main shaft, carrying with it the lock-cylinder, carrier, barrels, and locks. As the gun is rotated, the cartridges, one by one, drop into the grooves of the carrier from the feed cases, and instantly the lock, by its impingement on the spiral cam surfaces, moves forward to load the cartridge, and when the butt end of the lock gets on the highest projection of the cam, the charge is fired, through the agency of the cocking device, which at this point liberates the lock, spring, and hammer, and explodes the cartridge. As soon as the charge is fired, the lock, as the gun is revolved, is drawn back by the agency of the spiral surface in the cam acting on a lug of the lock, bringing with it the shell of the cartridge after it has been fired, which is dropped on the ground. Thus, it will be seen, when the gun is rotated, the locks in rapid succession move forward to load and fire, and return to extract the cartridge shells. In other words, the whole operation of loading, closing the breech, discharging, and expelling the empty cartridge shells is conducted while the barrels are kept in continuous revolving movement. It must be borne in mind that while the locks revolve with the barrels, they have also, in their line of travel, a spiral reciprocating movement; that is, each lock revolves once and moves forward and back, at each revolution of the gun.

The gun is so novel in its construction and operation that, as before remarked, it is almost impossible to describe it minutely without the aid of drawings. Its main features may be summed up thus:—

1st. Each barrel in the gun is provided with its own independent lock or firing mechanism.

2nd. All the locks revolve simultaneously with the barrels, carrier, and inner breech, when the gun is in operation. The locks also have, as stated, a reciprocating motion when the gun is rotated. The gun cannot be fired when either the barrels or locks are at rest.

This brief description will convince any intelligent person at all acquainted with mechanical principles, that the "Gatling battery," in its distinctive features, is unlike all other fire-arms.

There is a beautiful mechanical principle developed in the gun, to which I would direct special attention, viz., that while the gun itself is under uniform constant rotary motion, the locks rotate with the barrels and breech, and at the same time have a longitudinal reciprocating motion, performing the consecutive operations of loading, cocking, and firing without any pause whatever in the several and continuous operations.

Criticisms on the Gatling System.

And now, after this brief history and description of the "Gatling battery," I propose to notice the chief objections that have been urged against it, and to expose the unjust criticisms to which it has been subjected in Major Fosbery's communication, heretofore alluded to.

This distinguished Officer, it is true, cannot be said to have made a direct and open attack upon my battery; but his criticism, though covert, and certainly very ingenious, is no less calculated to mislead and damage, if left unexposed. For instance, the Major represents the "Gatling battery" as "belonging to the same general class," and "embracing the same general principles as the Agar and Claxton guns," which he had previously pronounced failures, and which have been generally condemned wherever tested, thus seeking to leave the impression, without directly avowing it, that the "Gatling battery" is deserving of a like condemnation.

Now, I undertake to say that, in the sense that all guns *shoot*, and in no other, can the "Gatling" be said to belong to the same general class, and to embrace the same general principles as the Agar or Claxton gun.

The Agar gun has one stationary barrel, which is firmly screwed into a massive breech-piece, which is also stationary. It has also one lock, which is stationary. Such being the case, how can it be said that such an arm involves the same general principles as the "Gatling," which has ten barrels and ten locks, all of which revolve? There would be as much propriety in saying Hoe's rotary printing press involves the same general principles as the old screw or lever press. A sheet of paper cannot be printed in a cylinder press unless the cylinder be rotated, nor can a shot be fired from the "Gatling" gun except when the barrels and locks are rotated.

Moreover, the "Gatling battery" loads the cartridges directly into the rear ends of the barrels, while the cartridges in the Agar gun are loaded in chambers or pieces of metal, which are detached from the barrel, thus firing across a joint causing much leakage of gas at each discharge. The "Gatling" was the first machine gun ever invented which loads the

cartridge directly into the rear ends of the barrels, thus preventing all leakage of gas at the breech.

The Claxton gun is a weapon of recent origin, having been constructed in 1868. It is made up of parts copied from other arms, and has no well-defined mechanical principle. It is a rude and imperfect affair, and is unworthy of an extended notice. It has two locks, and uses two barrels at a time, firing alternately. It is what may be termed a "rocking gun," for, by a kind of pump-handle lever, it is worked or turned, first to the right, and then to the left, in order to load and fire.

It will not be denied by Colonel Claxton, that he never thought of a machine gun until he saw the "Gatling battery" in 1867, when he accompanied Mr. Broadwell to Spain with it. His efforts to improve upon it, however, have proved abortive.

Major Fosbery, however, in view of these facts, has allowed himself —ignorantly, I believe—to pervert history and common sense, by saying that the "Gatling gun," invented six years previously, "belongs to" and is "an improvement on the Claxton gun." As well might he have said that Watts' steam engine "belongs to" and is "an improvement" on the Fulton or Corliss engines. The guns are entirely dissimilar in principle, and Major Fosbery, in assigning them to the same "general class, involving the same general principles," has obviously committed a mistake.

The Major has committed another mistake in assigning to the French the invention of the machine gun, and in claiming for their gun a superiority over all others. He says :—

"To the French in any case clearly belongs the credit of having "been the first to appreciate the importance of this subject, and in "spite of the many grave difficulties which attended their earlier essays, "to conquer them by laborious constructions and experiments, and "produce a weapon far in advance of anything possessed at the "present moment by any one of the civilized powers. That it will "fulfil their anticipations I have but little doubt, and should it do so, "it will to the full justify the outlay and labour expended on its con- "struction, and the cost of the mystery with which it has been their "care to surround it."

I have seen the French mitrailleur, for which Major Fosbery claims such superiority, and recognized at once in it some of the characteristics of the "Gatling battery," though instead of being a superior, I think it can be clearly demonstrated to be an inferior weapon.

It may be important to inquire from what quarter did the French derive their idea of a machine gun? Upon this point I have strong circumstantial evidence to submit to the public, from which they can draw their own conclusions.

I have heretofore stated that my first gun was manufactured in 1862, and was publicly exhibited in Indianapolis, Cincinnati, and Washington, and full descriptions of it published in the American and European papers. Being desirous of making my invention known to the French, as well as other Governments, I addressed, on the 29th day of October, 1863, a letter, accompanied with a full description of my battery gun,

to Major R. Maldon, of the French artillery, with the request that he would deliver the same to His Majesty the Emperor. That my invention, in its then condition, without the valuable improvements made subsequently, "excited a profound interest" with the Emperor and artillerists of France, the following translation of a letter from Major Maldon will show :—

"Ministry of War.
"Committee of Artillery.
"Paris, November 20, 1863.

"Monsieur,—I read the letter you addressed to me on the 29th of last October, and communicated it to the private office of the Emperor.

"In consequence of the answer received, I have to tell you that your cannon has excited a profound interest, and I ask of your kindness to answer the following questions that have been proposed to me :—

"1st. What are the results of the tests in regard to precision at the various distances it was tried ?

"2nd. What proofs have been made in regard to the solidity of your cannon ?

"3rd. What is the weight of the ball, and of the charge of powder, in the combination which gives the best results ?

"4th. Since your cannon has been adopted by the Government of the United States, there should be some official report upon the proofs which has caused its adoption. Can you send me a copy of such report ?

"5th. If the information which I ask you, and which, when received, will be transmitted to the Emperor, should cause His Majesty to desire that experiments be made in France with your system, under what conditions would you consent to send to France a cannon complete with all the munitions necessary to make conclusive proofs ?

"Do me the favour, Monsieur, to reply to the five questions which I have placed before you, and after I have received your reply, I will put the matter under the eyes of the Emperor, and cause you to know the decision of His Majesty.

"Receive, Monsieur, the assurance of my very distinguished consideration.

"Your servant,
"R. MALDON.
"Major of Artillery to the
"Committee of Artillery, Paris.

"Monsieur Richard J. Gatling,
"Indianapolis, U.S."

In reply to this letter, I gave definite answers to the questions asked, and then proposed to sell 100 or more of my guns to the French Government. This they declined, and before any further negotiations were had, the Government of the United States passed a law forbidding the exportation of arms or munitions of war.

This correspondence, it will be perceived, took place in 1863, and will go far, I think, to explain the origin of that "mysterious French mitrailleur," about which so much has been recently said and written. It is clear that it was not invented until *after* the character of the "Gatling battery" was made known to the French officials. When the information was conveyed to them that my battery was "a compound machine gun," consisting of "many barrels and many locks," is it not fair to presume that it suggested at once to the ingenious French artisans the mitrailleur, which is also a compound gun composed of many barrels and many locks, but without the rotary motion peculiar to the Gatling gun, and amenable to the objections urged against the

Montigny gun, which it very much resembles? The vast superiority of the armament of the Prussian troops, as demonstrated in their contests with the Austrians in 1866, justly alarmed the Governments of Europe, and had much to do in hastening the adoption and immense manufacture of the mitrailleur, even in its imperfect condition, by the French Government.

In view, then, of the fact that no notice of the French mitrailleur was published to the world, or in any way alluded to or mentioned, even casually or "mysteriously," until several years after the date of my invention, and that invention made known to the French Government, it is difficult to conceive how Major Fosbery can concede to the French the credit of being the first to appreciate the importance of the subject.

From the description of my gun given by Major Fosbery, I am forced to the irresistible conclusion that that distinguished Officer has either never seen it, or has given it but a very meagre and unsatisfactory observation and examination. He speaks of the barrels being "strongly fitted to a frame work, which is again surrounded by a metal cylinder." I need scarcely say, that the barrels are *not* "fitted to a framework," nor are they nor the framework "again surrounded by a metal cylinder." This description must belong to another gun, certainly not to the "Gatling." The rear ends of the barrels in the "Gatling gun" are screwed into a circular metal plate, and are supported at their forward end by another circular plate, and both of these plates are rigidly fastened upon and to a main revolving shaft, which is journaled at its front end in the front part of a frame, and in its rear end into a diaphragm, or partition in the breech-casing. The casing rests upon the rear part of the frame, and is firmly screwed to it, but it does not surround the frame or the barrels. He also states that "an opening in this cylinder permits the entrance, one by one, of the cartridges." Really, I would not recognize my gun at all in Major Fosbery's description of it. He has criticised my weapon without fully informing himself of its principle, details, and operations. There is no such "opening" in the "Gatling" gun as he describes. The cartridges are fed to the gun from feed-cases, through an opening in the hopper, which is placed over the "carrier" in front of the metal cylinder.

Again, in speaking of a recent trial of a Gatling gun at Vienna, in competition with a Montigny mitrailleur, Major Fosbery says, "The "rate of fire (of the Gatling) was found to average 280 shots per "minute, instead of 500 to 700, and almost every minute produced "some interruption of the firing."

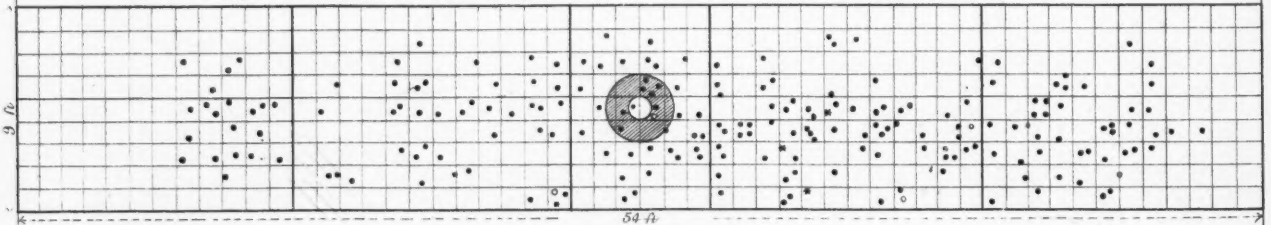
The Major speaks from hearsay, for he was not present at the trial, and there seems to be a difference, not slight either, between his statement and that of those who were present. Besides, the gallant Major, while finding fault with the trivial interruption in the firing of the "Gatling gun," satisfactorily explained hereafter, forgets to mention that the Montigny gun, which he champions so ably, broke down completely on the occasion alluded to, before 15,000 rounds had been fired, and required three weeks to be again put in order! An interruption of a minute or less on a field of battle, seems a grievous fault in the

J. Jobbins

RESULTS OF TARGET PRACTICE MADE AT VIENNA JULY 9TH 1869.

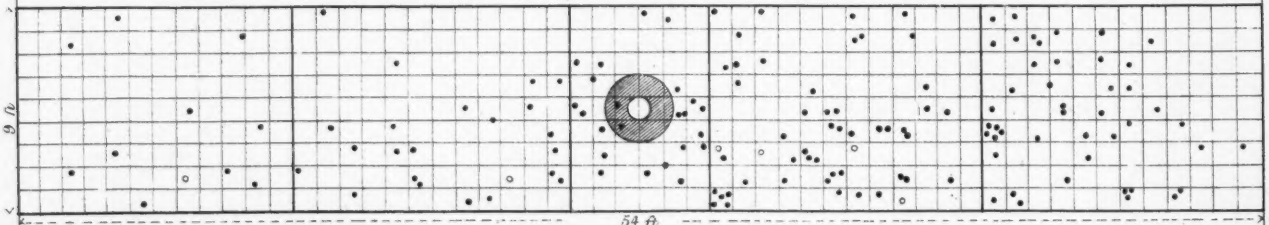
½ INCH GATLING GUN.

*Distance 800 paces.– * Trial Shots 3 – Shots 216 – • Sharp Hits 208. – ○ Hits which did not penetrate 5 – Total 213.*



·420 INCH GATLING GUN.

Distance 1200 paces.– Shots 191 – • Sharp Hits 149 – ○ Hits which did not penetrate 3 – Total 152.



Pl XII.

Major's eyes, but an interruption of three weeks is a matter of such little consequence as not to be deserving of mention!

I prefer to give the testimony of a gentleman who was present at the trial alluded to by Major Fosbery, and I am inclined to think the public will regard such evidence with more credence and consideration than that obtained from hearsay. I quote from Mr. Broadwell, of Carlsruhe:—

"The official programme of the late competitive trials at Vienna, "stated that 20,000 rounds should be fired from each gun, or until one "of them should break down, which the Montigny did on the third "day of the trial, and before 15,000 rounds had been accomplished by "it. This should have terminated the trials in favour of the Gatling, "but, for some reason, it was then decided to repair the Montigny, "which required three weeks' time, and complete the 20,000 rounds.

"The Gatling had fired its 15,000 rounds without a fault, but in "firing the remaining 5,000 rounds there were some hindrances. Those "of the first day were chiefly caused by the injury to the feed-cases, "supposed to have been done by some malicious person; those of the "last day were traced to some defective cartridges, which had been "clandestinely mixed with the Gatling ammunition, after it came "upon the shooting ground. But at no time, under all these dis-"advantages, was the fire of the Gatling interrupted for a period of "one minute."

It was the Montigny, therefore, and not the Gatling, which was "spiked and rendered useless,"—a slight mistake in the name!

Upon this testimony I submit the case as to the relative merits of the two guns on the trial at Vienna. I may add, however, that the small Gatling gun, used on the occasion, was not of the latest improvement.

In further comment upon the relative advantages of the two arms, Major Fosbery "confesses to feeling great doubts as to whether, for "war purposes, the Gatling will fulfil all necessary conditions," and contends that "the Montigny gun has the enormous advantages of sim-"plicity as compared with other systems."

As to whether the Gatling will fulfil all the necessary conditions for war purposes, time and trial must decide. No mere assertion of mine in the affirmative, or of Major Fosbery in the negative, will convince the public one way or the other. By the stern ordeal of trial, through which it has already passed, and to which it must further be subjected, will this question be definitely decided.

As to the claim of "simplicity," however, for which the Major alleges "enormous advantages" for the Montigny gun, that is a question easily settled. I am really surprised at the claim, and this surprise will, I doubt not, be shared by the public when they learn that the lock mechanism alone in the Montigny gun numbers more parts than there are pieces in the entire "Gatling gun."

The different parts of the lock mechanism in the Montigny mitrailleur used in the trials at Vienna, were counted, and found to be over 160; and yet Major Fosbery strangely claims "the enormous advantages of simplicity" for this complicated machinery, which was knocked out of

order in firing less than 15,000 rounds, and required three weeks to repair.

Indeed, I cannot but feel amused at the very ingenious description of this arm, given by Major Fosbery. He says:—"The Montigny "mitrailleur, of which a representation is given, consists of an assem- "blage of barrels contained in a wrought-iron tube, mounted on the "same principle as an ordinary field-gun, which, indeed, it somewhat "resembles in form. To this a massive breech-action is attached, "sliding between heavy iron plates. This is controlled by a jointed "lever, which is here represented as raised by a man working the gun, "and contains a simple contrivance for the separate and successive "ignition of the cartridges."

One would scarcely think, on a mere perusal of this description, that this "massive breech-action" is a mass of complex machinery. Yet so it is. As before stated, there are over 160 pieces in the lock mechanism alone of this weapon, so much vaunted for its "simplicity," and all these parts are adroitly styled a "simple contrivance for the separate and successive ignition of the cartridges." Does the enclosing the works of a watch in a massive case render its mechanism any the less complicated?

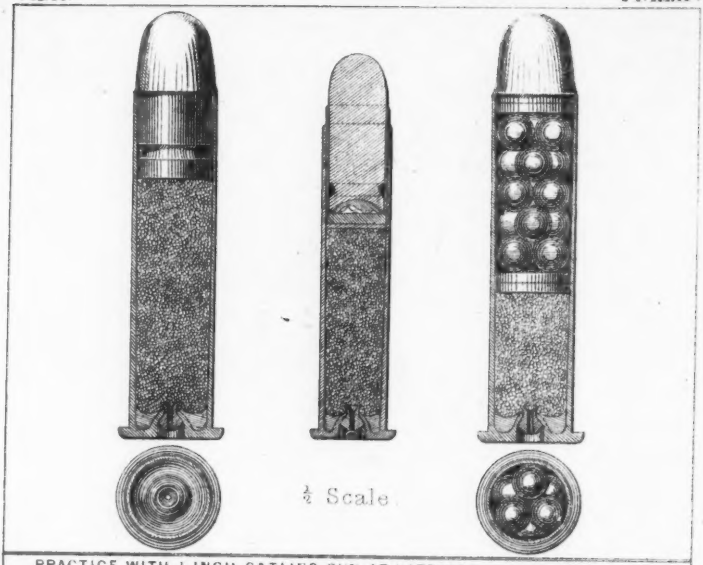
All this complex lock mechanism in the Montigny gun being attached to and enclosed in a "massive breech-action," forms, as it were, an entirety, and should any of the various parts get out of order, which is likely to happen in battle, and which did happen at the trial in Vienna, before even 15,000 rounds were fired, the whole machine would have to be taken to an armoury for repairs, and if three weeks were consumed in such repairs, as at Vienna, it may be considered extremely doubtful whether the enemy would await the completion of the job.

Not so the "Gatling gun." If there is one thing more than another for which it can justly claim superiority it is its simplicity, as has been repeatedly stated by the eminent Army and Naval Officers who have witnessed its operations. Its locks are made interchangeable, and are strong and durable, but should they get out of order, the gun is so constructed that any one or all of the locks can be, in a few moments, taken out, and new ones inserted in their places, and so the gun can be kept in perfect working order at all times on the field of battle. It will not be denied that this is a feature of the greatest value, and is peculiar to the "Gatling" system, for no other machine gun is made with removable locks and interchangeable in all its parts.

The lock mechanism is the most essential part of a machine gun, and is the only part which is liable to get out of order from use, for all the other parts are of sufficient strength to withstand all usage incident to the service. In this most important particular the Gatling stands pre-eminent.

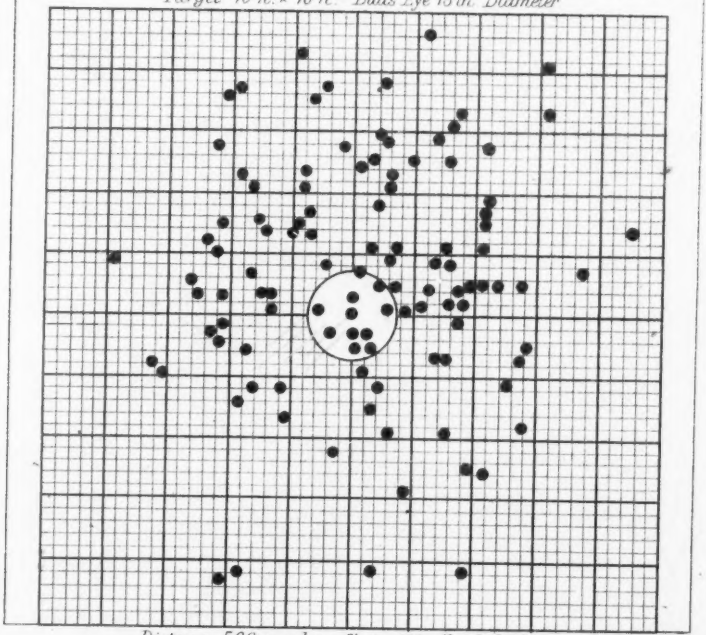
Another objection urged by Major Fosbery against the "Gatling battery" is, that such is the rapidity of its fire, that "it must be evi- "dent that many minutes would elapse before it would be possible to "fire again, owing to the heating and fouling of the barrels, which "would necessarily take place."

In refutation of this objection, I will let the gallant Major answer



PRACTICE WITH 1 INCH GATLING GUN AT HARTFORD, U.S.A. NOVR 3 1869

Target 10 ft. × 10 ft. Bulls Eye 18 in. Diameter



Distance 500 yards.– Shots 110 all of which hit. J. Jobbins.

himself. The same objection having been urged against the Montigny gun, he thus disposes of it;—

"I have frequently been asked, 'But pray, Sir, what is the use of a "'gun that can fire twenty shots a minute? In five minutes your "'men would exhaust the whole of their ammunition, your gun be "'red hot, and the line engaged without a round of ball cartridge. No "'one should fire more than six or seven shots in a minute, and a gun "'is useless, or even mischievous, which enables them to do so.' Such "questioners seem to me to lose sight of the fact, that the power of "discharging twenty rounds in one minute, conveyed also that of dis-"charging five shots in fifteen seconds, and that on those fifteen "seconds and the five shots fired per man fired in them, would "often depend the forcing or the preservation of the key of a position "necessary to the safety of an army, or the repulse of an attack on "lines or squares menaced by greatly superior numbers. In like "manner the rapidity of fire of a mitrailleur battery must receive its "due consideration. It may never be necessary to fire twelve rounds "per gun per minute during any action they may ever be engaged "in, but in their capacity for such rapid firing reside a power and "an advantage which might at any moment prove inestimable.

"It is on the final minutes and portions of minutes that the suc-"cesses or failures of great movements as frequently turn, as on the "ability, skill, and forethought employed in preparing for them. A fire "of unexampled weight and severity, thrown in at a critical place "and moment, will often be more decisive in its results on the fate of "the day, than whole hours of distant cannonading or long-range ball "practice. It was in short intervals of an overwhelming rapid fire "that the Prussians found their breech-loaders give them their most "decisive advantages."

I submit if the Major, in his defence of the Montigny mitrailleur, has not successfully answered the objection he urged against the "Gatling gun." But if his logic is true as to the Montigny gun, how much truer is it of the Gatling, when we consider that the former is a solid mass of barrels, which are discharged in a volley, while the latter is made of single barrels, with space between them for the free circulation of air and radiation of heat. Scientific and practical men will acknowledge that such a weapon will not heat and foul so soon as one composed of a solid mass of barrels, admitting no circulation of air and radiation of heat.

There is still another peculiar and valuable feature in the "Gatling" system, which should commend it as a military arm for special service, range, and accuracy. It fires not by volleys, but a shot at a time, in rapid succession, thus dividing the time used in rapid firing into equal parts between each discharge, and preventing an accumulation of recoil. Thus, the Gatling system admits of larger charges and heavier balls, consequently greater range than can be used in any other machine gun. For instance, the larger sized "Gatling" fires a shot at a time, in rapid succession, weighing a half-pound, without the recoil displacing the gun-carriage. This firing a shot at a time also allows a lateral motion of the gun being kept up during the time of firing, which result is

attained in the Broadwell carriage upon which the "Gatling guns" are mounted.

Now, suppose a volley of this class of ammunition was fired from a 37-barrelled Montigny gun, would not its carriage by the accumulative recoil, be sent back to a great distance, necessitating re-sighting the piece after each volley? Most clearly so. It is true the mitrailleur can be fired a shot at a time, but to do so would greatly lessen its rapidity of fire.

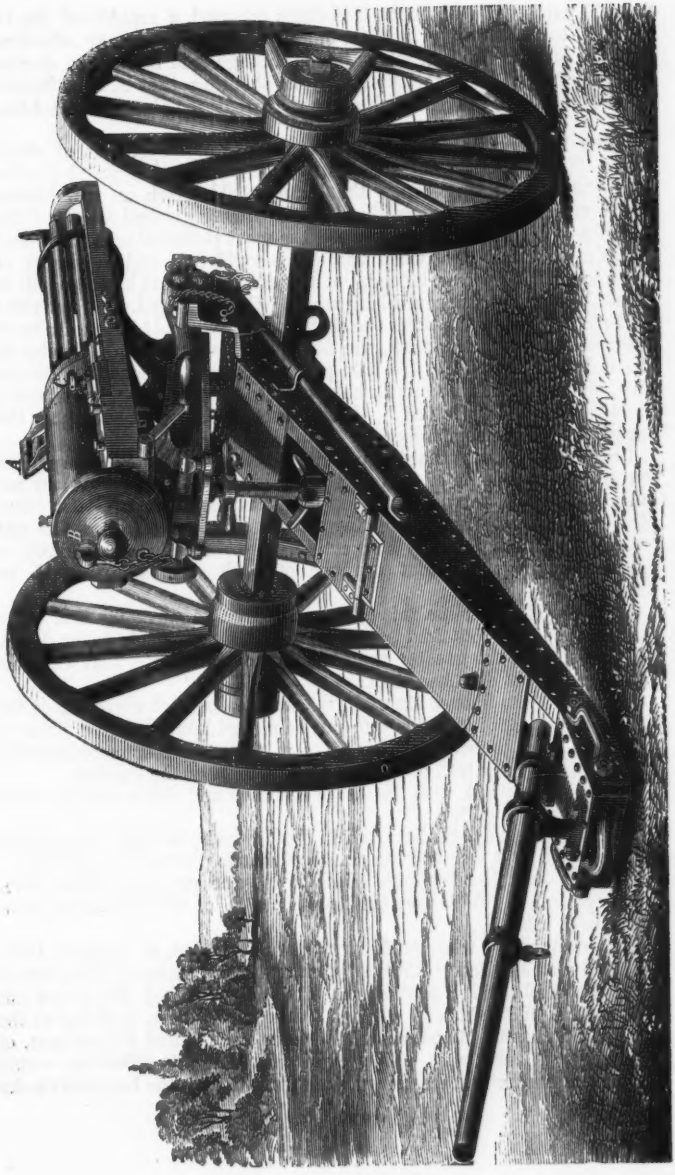
Again, the steel barrels used in the 1-inch calibre "Gatling" gun weigh each 28 lbs. Now, if a Montigny, with its 37 barrels, should be made of 1-inch calibre, the barrels alone would weigh over 1,000 lbs. Of course this would make the weapon, including its massive breech-action, &c., too heavy for field service. To reduce the number of its barrels would again lessen its rapidity of fire and efficiency.

There is another important fact which it may be as well to state in this connection. The largest sized "Gatling gun," with a range of 2,000 to 3,000 yards, can be taken apart, packed on mules, and carried up or across mountains, and re-assembled in a few minutes. With no other heavy machine gun can this be done, and here again the "Gatling" bears the palm of superiority.

The effectiveness of the large calibre "Gatling battery" does not depend, as some suppose, wholly upon feeding the cartridges to the gun from the feed-cases. The large cartridges used in this arm can be fed to the gun when the hopper is thrown back, by an active man, by hand, at the rate of 90 to 100 per minute; and this rate of discharge is, perhaps, quite fast enough when long and continued firing is to be kept up. The use of the feed-cases and rapid firing need only be resorted to in repelling a charge or in forcing the key of a position.

In feeding the cartridges to the gun by hand, all that is necessary is for one man, when the hopper is turned back, to lay the cartridges one at a time, into the grooves of the carrier. The revolving the gun by the man at the crank will load and fire the cartridges in rapid succession. It will take no more time to feed the cartridges to the gun by hand, in the way stated, than it would, to load like cartridges into the feed-plates of a mitrailleur.

It is true, the larger sized improved "Gatling gun," of which a representation is here given, and which has an effective range of from 2,000



to 3,000 yards, has, when the feed-cases are used, a rapidity of fire of only 150 to 200 shots per minute, but I regard it as far more effective than the smaller Gatling, which has less range, and more than double the rate of fire. It is the quality of the shooting, that is, the efficient execution at long range, which gives the greatest value to a machine-gun.

Major Fosbery, in his able communication, truly says, that at short range, 800 yards, the mitrailleur would be more than a match for the field-gun, but at long range the latter would smash up and destroy the former. "Had the gun," admits this distinguished Officer, "the "choice of distance, a duel between the most powerful mitrailleur and "a comparatively light rifled field-piece could only end in favour of "the latter." Very true, indeed, but how different would be the result in a duel between an improved long range "Gatling," and a "light rifled field-piece," giving the latter the choice of distance. If both guns were unloaded to commence with, the field-piece never would be loaded at all; if both were loaded, the field-piece could not be loaded a second time, nor would a horse or man belonging to it survive the first minute's practice from the "Gatling." I am indebted to Major Fosbery for the suggestion of the comparison.

I entertain no doubt that the principle upon which the "Gatling" gun is constructed, admits of its range being extended, so as to cover not only the interval between musketry and artillery fire, but that occupied by artillery, thus combining in one arm the effectiveness and execution of both infantry and artillery fire. It must be evident to every thinking mind that the use of such a weapon would be invaluable.

Let us briefly examine this question. First, as musketry fire. The execution of the shots fired from a small "Gatling" would be, no doubt, shot for shot, much greater than the fire of infantry. This valuable result grows out of these facts:—

When the gun is once sighted, its carriage does not move but at the will of the operator, and the gun can be moved laterally when firing is going on, so as to sweep the sector of a circle of 12 or more degrees, without moving the trail or changing the wheels of the carriage.

It can be trained with far more accuracy and delicacy than small arms from the shoulder.

It has no nerves to be disturbed in the din and confusion and carnage of the battle field, nor will the smoke of battle prevent its precision.

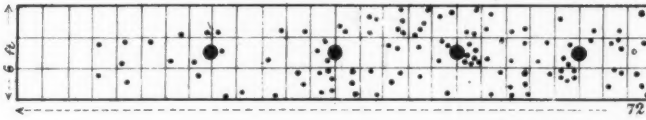
There is another advantage which it may be proper to state here. The exposure of life is very small with a gun of this character, compared with infantry.

In a competitive trial, made at Carlsruhe, Baden, in August, 1869, between a small sized "Gatling" gun and 100 infantry soldiers, armed with the celebrated "needle-gun," the "Gatling" at 800 paces put 88 per cent. of its shots in a target, while the soldiers, in firing at the same sized target and at the same distance, only placed 27 per cent. of their shots in the target. Who can doubt that this difference would have been greater had the firing taken place during the heat and smoke of battle?

RESULTS OF TARGET PRACTICE MADE AT CARLSRUHE BADEN AUGUST 1869 BETWEEN

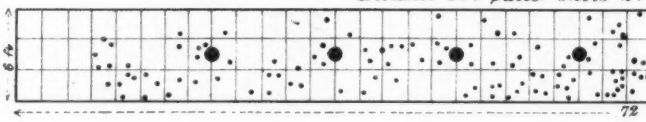
INFANTR

Distance 800 paces - Shots 721



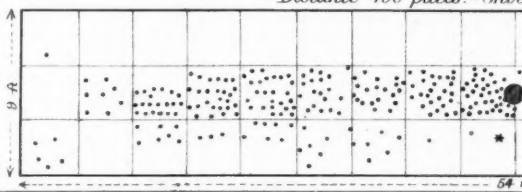
½ INCH GATL

Distance 800 paces - Shots 24



PRACTICE MADE AT VIENNA JULY 17TH

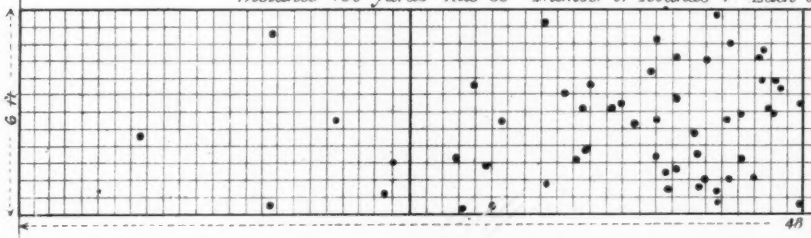
Distance 400 paces. - Shot



RESULTS OF TARGET PRACTICE MADE AT FORTRESS MONROE.

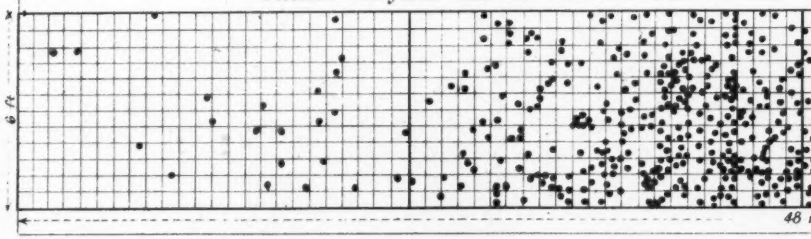
24 Pdr HO

Distance 150 yards - Hits 89 - Number of Rounds 4 - Each



1 INCH GATL

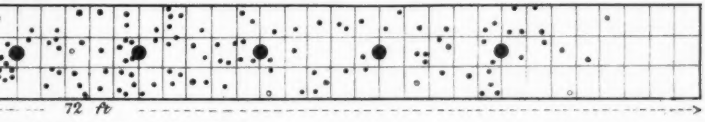
Distance 150 yards Hits 691 - Number of Shots 101 each G



BETWEEN 100 INFANTRY SOLDIERS ARMED WITH THE "NEEDLE GUN" AND A SINGLE "GATLING GUN"

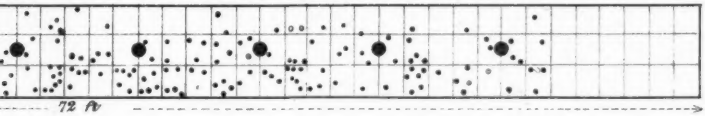
FANTRY TARGET.

Shots 721.– Hits 196.– Time 1 Minute.



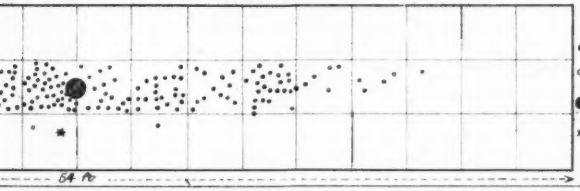
H GATLING TARGET.

Shots 246 – Hits 216.– Time 1 Minute.



JLY 17TH 1868. — ½ INCH GATLING TARGET.

ces.– Shots 399 Time 2 Minutes.

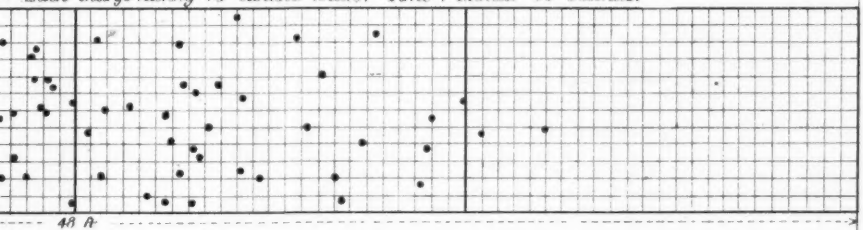


• *Shots which penetrated.*
° *Shots which did not penetrate.*
● *Bulls-eyes.*
* *Trial Shots.*

MONROE. U.S.A. BETWEEN 24 Pdr HOWITZER AND A 1 INCH GATLING GUN

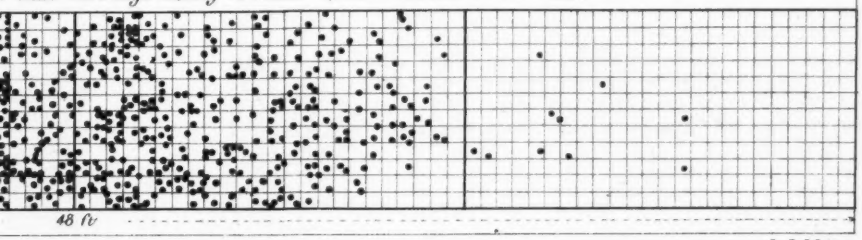
Pdr HOWITZER.

– Each charge having 48 Canister Balls. – Time 1 Minute 30 Seconds.



H GATLING TARGET.

each Cartridge having 16 Balls – Time 1 Minute 30 Seconds.



J. Jobbins

Second, as artillery. There is abundant data to prove that only a small per cent. of the missiles fired from field-guns in the excitement of battle prove effective. During an action, and when the smoke frequently prevents the enemy being seen, the firing is done, in many cases, in the most random manner, and especially is this so when the ground is uneven, and the enemy is frequently changing his position. The gun is also changing its position, particularly when the enemy is pressing forward, and rapid firing is kept up. Often, in such cases, the gun is not moved forward, for want of time, to its original position after each discharge, but is fired in the position in which the recoil has left it. And this is repeated while the battle lasts, when, at its close, it is often found that the gun has receded for a considerable distance from its first position. It must be evident that, under such excitement and conditions, the most of the missiles discharged have failed to do execution.

On this head, the testimony of an experienced artillery Officer may not be out of place. I quote from Major Fosbery:—

"With the field-gun in its best condition we produce per round " 20 effective fragments, or bullets, capable of inflicting serious wounds " or death, and we can throw these into a column or other body of " troops up to 1,500 yards. We can throw 2½ such rounds per minute " under favourable conditions, or 5 rounds in two minutes of time, that " is 100 such effective pieces. When these pieces come to be analysed, " we find that some are segments or bullets, some broken pieces of " the envelope of iron which fits the gun, and carries them up to their " destination. We employ for the purpose at the gun itself a certain " amount of apparatus for piercing the fuzes, cutting or otherwise " adjusting them; or we employ a fuze already prepared, which depends " on some careful adjustment of the gun itself for its efficacy. When " all is done, about one-half of the weight of metal put into the gun " is finally effective at the object.

"But if this is the case, and it would be difficult to prove that more " is so, it must be evident that somewhere a great waste of material " occurs. For could a larger portion of metal be made effective, it is " clear that it would be useless to carry into the field so large a weight " as we now do, in order to produce an equal effect; but if a less " weight of metal would suffice, then also would a less amount of " powder be required to drive it, a gun of smaller calibre might be " used, and the whole of our field equipments would become easier to " move, handier in the working, requiring fewer men and fewer horses " for its transport and service; and as a matter of course, both in a " military and in an economical point of view, fitter for the service of " the country.

"So far is this now from being the case, that we find the 9-pr. " guns of the horse artillery unable to produce the effects which we " would wish to see, and a proposition entertained for exchanging " them for 12-prs., which will doubtless add to the efficiency of their " fire, though the additional weight to be dragged, must detract to a " large extent from their mobility. Supposing for a moment such a " change to be carried out, and a horse artillery battery of 12-prs. to

"be brought into action, not to breach a wall, batter a farm-house, "nor oppose an enemy's artillery, but merely to play upon troops "either awaiting an attack, or forming to make one, what do we find? "We find guns weighing 900 lbs., each brought rapidly to the front, "with limbers and wagons weighted with at least twice as much "powder, lead, and iron as will ever produce, under the best of circum- "stances, either death or wounds to an enemy; and we find these "deaths and wounds dealt out very slowly indeed, at the rate only of "about 50 per minute under these exceptionably favourable conditions.

"If a 'range-finder' is used, a minute and a half is consumed in "finding the distance of the enemy; if it be not used at any "but the shortest distance, the fire is mere guess work, and may "be either good or bad, with a strong presumption in favour of the "latter. Superior as our artillery is acknowledged to be, we can "scarcely wonder, knowing what we know of its performances, at the "failure of either the Austrian or Prussian rifled field services to "influence largely the fate of the battles, where both were so freely and "ably made use of. Neither succeeded in any instance, as far as I am "aware, in stopping the advance of infantry, or even in greatly imped- "ing the operations of cavalry in the field, though doubtless both "were efficient and well served."

In another part of his communication, Major Fosbery says :—

"In order to produce these twenty fragments (above alluded to) "and render them efficient, many independent operations must be "truly performed, and even then sudden gusts of wind, or considerable "barometric variations may render all of no avail by their influence on "the flight of the projectile, by delaying or accelerating the burning "of the fuzes. * * * * * * * *

"The gun must be laid between each discharge, an operation demand- "ing time and care, necessitating a clear view of the object, and all "but impossible to get exactly repeated by the most highly-trained "and skilful gunners when on an artillery practice-ground, and neither "greatly pressed for time, nor deprived, in however small a degree, of "that *sang froid* which few persons possess completely, when exposed "to a lively fire, and endeavouring to crush it by the rapidity of their "own."

This is the evidence of an Officer who has had the best opportunities of judging, and whose experience entitles him to speak advisedly on the subject.

At the risk of being considered tautological, allow me to enumerate the advantages of the larger sized "Gatling gun" over such an arm, when used to play upon troops either awaiting an attack or forming to make one.

1st. Its great range, equal to that of the field gun for all practical purposes, and its greater accuracy and precision.

It is the use of the elongated leaden bullet which has great specific gravity and small air resistance, that gives the "Gatling gun" its superior range and precision.

2nd. Its rapidity and continuity of fire, 200 shots per minute, when well served, each ball weighing a half-pound; 1,200 shots a minute

from a single battery of six guns; 7,200 shots per minute from six batteries! "It would be difficult to find the troops who could face "such a hailstorm as this."

3rd. No re-sighting and re-laying are necessary between each discharge. As before stated, "when the gun is once sighted, its carriage "does not move, except at the will of the operator, and the gun can "be moved laterally when firing is going on, so as to sweep the sector "of a circle of 12 degrees or more without moving the trail, or chang-"ing the wheels of the carriage." The smoke of battle, therefore, does not interfere with its precision.

4th. It is lighter than a 12-pr., therefore, more easily moved, and requiring fewer horses and men to serve it.

5th. The balls of the "Gatling gun" ricochet for a greater distance than the balls or shells of the field-piece.

6th. The Gatling system is more economical, not only in requiring less horses and men to manage the gun, but also in its ammunition.

The ammunition now used in the "Gatling gun" has been greatly improved. I am free to confess that the large 1-inch metallic case ammunition first made for the use of the larger sized "Gatling gun," and which was used in the first European trials, proved defective. Its defects grew out of the fact that the cases or shells were made out of sheet metal, which had not the proper solidity to enable them to withstand even the small charge of powder then used. The result was, that in firing, the heads of some of the cartridges came off or burst, interrupting, of course, the firing. Moreover, the cartridge shell-extractors first used in the locks were imperfect, failing, at times when the heads of the cartridges were small, to extract the shells after they had been fired.

I am happy to say that all these defects have been entirely overcome by subsequent improvements.

Instead of making the cartridge cases or shells of thin material, as in the first instance, they are now manufactured by the aid of powerful machinery, out of sheet metal, which is $\frac{1}{10}$th of an inch thick, the heads are made solid, and, in order to increase their solidity, solder is used in their base. The shells are now so constructed as to admit of being reloaded. Indeed, they have been loaded and fired 100 times, without being perceptibly injured.

If one of these shells, or "loading chambers," cost, say, 6*d*., and it can be reloaded and fired on an average of, say 50 times, without injury, it is evident that it must be cheaper than ordinary metallic cartridges, the shells of which can be fired only once.

I am of the opinion that this class of reloading metallic ammunition will, ere long, be adopted by all civilized nations. These cartridges are waterproof, and strong enough to stand all usage incident to the service. They are not only cheaper, but they are safer in the transport, and are of less weight, and occupy less space, requiring, therefore, fewer men and horses for their transportation and service than artillery ammunition. Besides, if this system of reloading cartridges is adopted, loading machines, with extra balls and powder, can be taken along, and men can be detailed to reload the shells after they have been fired on

the field of battle. In this way, a supply of ammunition can always be kept up in time of action.

The Montigny Mitrailleur.

A few words as to the Montigny mitrailleur, before passing to the general subject of machine guns, with which I propose to close this communication. It has one characteristic feature of the "Gatling gun," viz., in its being composed of a number of barrels, and having a lock or firing mechanism for each barrel. In other respects it is a very different arm.

I acknowledge that the Montigny is a very creditable invention, and, no doubt, since it has been improved by so competent an officer as Major Fosbery, is an effective weapon at short range. It has, however, a few radical defects. The prominent advantages of the "Gatling" over it, or, indeed, over any other machine gun, may be summed up thus:—

1st. The "Gatling" has much greater effective range.

2nd. It has greater accuracy of fire, which is equivalent to economy of ammunition.

3rd. The greater demoralising effect produced upon the enemy by the continuous fire of the "Gatling," as compared with the distinctly separate salvos of the Montigny.

4th. Greater strength and simplicity of mechanism.

5th. The "Gatling" system is equally well adapted to large or small calibre, while the Montigny is necessarily confined to small calibre.

6th. The projectiles of the large "Gatling," like those of field artillery, may be either solid shot, shell, or canister. It is quite practicable to increase the calibre of the "Gatling," to throw a shell of one pound weight or more, and thus prove a valuable auxiliary to field artillery.

7th. If any of the ten locks of the "Gatling," all of which work independently, but in harmony with each other, and constitute the only breakable part of the machine, should get out of order, the injured lock may be quickly withdrawn from the gun, and replaced by a reserved lock, and thus restore the gun to its original perfection. So little time is required for this, that it may be done in the presence of the enemy, if necessary. If, however, any similar accident occurs to the Montigny's locks, the gun is for the time entirely disabled, and must be taken to the shop for repairs.

8th. The construction of the "Gatling" carriage is such that the gun can be given a lateral or sweeping motion, without interruption to its continuous fire, and thus distribute its fire along a line of 12 degrees or more of the enemy's front. This arrangement is indispensable to an arm which fires so rapidly, as it would otherwise waste a large quantity of ammunition upon a single point, where there was no longer any work to be done.

9th. The "Gatling gun" fires with extraordinary rapidity, but always in distinctly single shots, so that the tendency to recoil is only that produced by a single shot, and this is entirely overcome by a simple device on the trail of the carriage. The true elevation having, there-

fore, been once obtained, any desired number of shots may be rapidly and accurately delivered, without any further adjustment of the gun.

This peculiarity of no recoil in the "Gatling gun" is of special value in the defence of bridges, fords, mountain passes, streets of cities, &c., &c., for the reason that frequently such points are attempted during darkness, fog, or storm, when the movement of the enemy cannot be accurately observed. "Gatling guns" having once been properly located and accurately directed upon the threatened points, are ready at any time to pour their deadly fire with certainty of effect; while the Montigny, or any other gun, placed under similar circumstances, after having delivered the first fire, must necessarily be relaid, and fired at random, and, therefore, probably with but little effect.

10th. The barrels of the "Gatling" being quite isolated from each other, their expansion and contraction are equal and uniform, and, therefore, they sustain no injury, such as is likely to occur to the Montigny system, where the barrels are massed together and enclosed in an iron casing.

11th. The greater safety, convenience, and economy of space attending the transportation of the "Gatling" ammunition, when packed for service.

12th. The "Gatling" small calibre can be effectively operated by two men, and fire as many rounds in a minute as the Montigny can with four men.

13th. The feeding drums and feed cases of the "Gatling" are all capable of being used with any gun of the same calibre, while the loading plates of the Montigny can only be used in the one gun, for which they were specially made. If they should, therefore, become mixed, as is likely during a campaign, very great inconvenience, and, perhaps, disaster might be the result.

14th. The Montigny discharges its 37 barrels almost in a volley, and the escape of the gas from the barrels first fired, must have a tendency to deflect some of the other balls, and thus affect the accuracy of its fire. The "Gatling," as stated, fires continuously a shot at a time, and thus avoids all deflections of the balls.

Conclusion.

After the above demonstration of the vast superiority in very many particulars of the machine gun, especially the "Gatling," as a weapon of war over the arms in present use, is it not evident that they will be extensively employed in future wars by all civilised nations? The "fossil remains" of a by-gone age may prefer to let things run along in the "time-honoured grooves," but improvement is the order of the day. Progress is the genius of the age. The mind of man has awakened from its lethargy, and is eagerly pressing forward to the accomplishment of greater results than even those which have rendered this century renowned in the history of the world.

On the road, in the field, in the steamship, and in the factory, we can see the wonders that machinery has accomplished. What valid reasons can be assigned why it should not take the same place in warlike

operations as it has already done in the arts of peace? Why can it be applied to the workshops, and not to the battle field?

The same class of men who doubted that the railway would ever take the place of the stage-coach; the reaper and mower, of the old-fashioned sickle; the spinning jenny of the "time-honoured" spinning-wheel, &c., may dogmatically decide in the negative; but intelligent men, who have carefully watched and noted the march of improvement and the steady development of new ideas, will perceive and acknowledge that the day is not far distant when machine guns will be extensively employed on the battle field; and the nation that is enabled to purchase the most of them, and to serve them in the most scientific and perfect manner, will best preserve the lives of its soldiers, and snatch victory from the standard of its opponent.

It requires no gift of prophecy to predict this result; and in the firm conviction that this is too apparent to longer delay the adoption and use of this class of weapons, I suggest that they should form a new arm, distinct from infantry, cavalry, and artillery. In other words, regiments should be composed of machine guns, as of infantry, cavalry, and artillery; otherwise their effectiveness would be greatly impaired.

Of course, all elements and classes of arms, which make up an army, should be under the control of one mind; but I repeat, "machine gun regiments," while they form parts of corps, divisions, and brigades, should be under the separate control of Officers who are well informed as to their manipulation and use. In such case they would be much more effectively used, and there would be a laudable rivalry between the Officers and men serving them and those serving the other arms.

The reader is referred to the targets hereto annexed. Lately improved "Gatling guns," however, are capable of producing much better results than are here shown.

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